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WATER METALS NO. 3

STUDY NUMBER 23

ANALYTICAL REFERENCE SERVICE

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U. S. DEPARTMENT OF HEALTH, EDUCATION, AND WELFARE
Public Health Service

WATER METALS NO.3

STUDY NUMBER 23

Report of a Study Conducted by the

ANALYTICAL REFERENCE SERVICE

Raymond J. Lishka

Training Program

Robert A. Taft Sanitary Engineering Center

U.S. DEPARTMENT OF HEALTH, EDUCATION, AND WELFARE
Public Health Service
Division of Water Supply and Pollution Control
Cincinnati, Ohio
1965

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Public Health Service Publication No. 999-WP-36

FOREWORD

The Analytical Reference Service is conducted by the Training Program of the Robert A. Taft Sanitary Engineering Center for the evaluation of laboratory methods in the environmental field. Cooperative studies by member organizations, through analysis of identical samples and critical review of methodology, provide the mechanism for:

1. Evaluation of analytical procedures, including precision and accuracy, by comparison of the procedures and results reported by participating laboratories.

2. Exchange of information regarding method characteristics.

3. Improvement or replacement of existing methods by development of more accurate procedures and by development of new methodology for determination of new pollutional components.

Samples are designed to contain measured amounts of selected constituents. Decisions as to qualitative makeup are made by the ARS staff, the membership, and consultants. Notice of each study is sent to the entire membership.

A portion of the study sample with accompanying data forms for reporting numerical values; a critique of the procedures used; and comments on modifications, sources of error, difficulties encountered, or other pertinent factors is then shipped to each of those who express a desire to participate. The results of each study and comments are compiled and a report is prepared.

Although the Analytical Reference Service studies were initially directed toward examination of water, they now include air, milk, and food. Some studies are periodically repeated for the advantage of new members, to evaluate new methods, or to reevaluate existing methods.

The selection of studies is guided by the responses to questionnaires periodically circulated among the membership, which now includes 289 Federal, state, and municipal agencies; industries; universities; consulting firms; and foreign agencies.

James P. Sheehy
Director, Training Program

ACKNOWLEDGMENTS

Mike Taras, Chairman, Standard Methods Committee of the American Water Works Association, helped Earl F. McFarren, Chief, and Foymae Kelso West, former Chief, Analytical Reference Service design the study, and the American Water Works Association, Inc., provided copies of the methods of analysis for water metals which now appear in the 12th edition of Standard Methods for the Examination of Water and Wastewater.

D.G. Ballinger, Supervisory Chemist, Technical Advisory and Investigations, Water Supply and Pollution Control; J.M. Cohen, Chemist, In Charge, Engineering Research; and R.C. Kroner, Chief, General Laboratory Services, National Water Quality Network; reviewed the final manuscript for technical correctness. The latter laboratory also provided special spectrographic analyses of the sample and container.

J.M. Matthews, Chemist, Analytical Reference Service, assisted in the preparation of the sample and checked the accuracy and stability of the sample by performing many analyses of aliquots of the sample before and after these were mailed to the participants.

R.T. Cope, Statistician, Analytical Reference Service, analyzed the data and prepared the bar graphs and probability paper plots.

STUDIES COMPLETED AND REPORTED

Water-Minerals	Calcium, magnesium, hardness, sulfate, chloride, alkalinity, nitrite, nitrate, sodium, and potassium. Studies completed in 1956, 1958, and 1961.
Water-Metals	Lead, copper, cadmium, aluminum, chromium, iron, manganese, and zinc. Studies completed in 1957 and 1962. These same metals plus silver. Study completed in 1965.
Water-Fluoride	Fluoride in the presence and absence of interferences, with and without distillation with the use of a specified procedure. Studies completed in 1958 and 1961.
Water-Radioactivity	Gross beta activity. Studies completed in 1959 and 1961. Gross beta and strontium-90 activity. Study completed in 1963.
Water-Surfactant	Surfactant in various waters. Studies completed in 1959 and 1963.
Water-Oxygen Demand	Biochemical oxygen demand and chemical oxygen demand. Study completed in 1960. Chemical oxygen demand. Study completed in 1965.
Water-Trace Elements	Arsenic, boron, selenium, and beryllium. Study completed in 1962.
Freshwater Plankton	Evaluation of the precision and accuracy obtainable by the use of various methods of plankton counting and identification. Study completed in 1964.
Air-Inorganics	Chloride, sulfate, fluoride, and nitrate in aqueous solution and on glass-fiber high-volume filter mats. Study completed in 1958.
Air-Lead	Filter-paper tape impreganted with lead. Study completed in 1961.
Air-Particulates	Microscopic identification of some common atmospheric particulates. Study completed in 1964.
Air-Sulfur Dioxide	Sulfur dioxide in air by the use of a specified method. Study completed in 1963.
Milk-DDT Residue	DDT in milk. Study completed in 1962.

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PARTICIPANTS IN THIS STUDY

Alabama Water Improvement Commission
Anaconda Company, Grants, New Mexico
British American Research and Development Company
British Coke Research Association, Chesterfield, Derbyshire, England
Calgon Corporation, Hall Laboratories Division, Pittsburgh, Pennsylvania
California State Department of Public Health (Berkeley)
California State Department of Public Health (Los Angeles)
California Water Service Company, San Jose, California
City of Charlotte, Water Department, North Carolina
Colorado Department of Public Health
Connecticut State Department of Health
Culligan Incorporated, Northbrook, Illinois
Dearborn Chemical Company, Lake Zurich, Illinois
Department of Health Services and Hospital Insurance, Vancouver, Canada
Department of National Health & Welfare, Vancouver, Canada
Division of Preventable Diseases, Nashville, Tennessee
Durham Department of Water Resources, North Carolina
Erie County Laboratory, Buffalo, New York
Environmental Health Laboratory, Patrick AFB, Florida
Environmental Health Laboratory (SGHK), Kelly AFB, Texas
Fairbanks Morse, Inc., Research Center, Beloit, Wisconsin
Flint Water Plant, Department of Public Works & Utilities, Michigan
Fourth US Army Medical Laboratory, Fort Sam Houston, Texas
Freeport Sulfur Company, Belle Chasse, Louisiana
Hawaii Department of Health
Hyperion Treatment Plant, Los Angeles, California
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Industrial Chemicals, Incorporated, South Bend, Indiana
Kentucky Department of Health
Los Angeles County Flood Control District
Los Angeles Department of Water and Power
Los Angeles Department of Water and Power, Sanitary Engineering Divison
Louisiana State Board of Health
Louisville Water Company, Incorporated
Maryland State Department of Health
Massachusetts Department of Public Health
Metropolitan Water, Sewage and Drainage Board, Sydney, Australia
Metropolitan Water District, La Verne, California
Michigan Water Resources Commission
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Nebraska State Department of Health
New Hampshire State Department of Health
New Jersey State Department of Health
New York City Health Department

New York City Department of Health
New York State Conservation Department
New York State Health Department
North Carolina Department of Water Resources
Norwegian Institute for Water Research, Norway
Ohio State Department of Health
Omaha Metropolitan Utilities District
Pennsylvania Department of Health
Permutit Company, Limited, London, England
Philadelphia Surburban Water Company
Public Health Service, EEFP, Food Chemistry, Cincinnati, Ohio
Public Health Service, GLIRBP, Chicago, Illinois
Radiation Detection Company, Mountain View, California
Regional Environmental Health Laboratory (LSGHM), McClellan AFB, California
Rensselaer Polytechnic Institute, Troy, New York
Roy F. Weston, Incorporated, West Chester, Pennsylvania
St. Louis County Water Company, Missouri
Scientific Research Council, Kingston, Jamaica, West Indies
Sixth U.S. Army Medical Laboratory, Fort Baker, California
State of Wisconsin, Laboratory of Hygiene
Tennessee Stream Pollution Control Board, Nashville, Tennessee
Tennessee Valley Authority, Occupational Health Branch, Wilson Dam, Alabama
Texas State Department of Health
Tracerlab, Richmond, California
University of Beograd, Civil Engineering Laboratory, Beograd, Yugoslavia
United Kingdom Atomic Energy Authority, Didcot, Berkshire, England
U.S. Geological Survey (Denver)
U.S. Geological Survey (Sacramento)
Vermont Department of Water Resources
Vermont State Department of Health
Virginia State Department of Health
Washington State University
Water Research Association, Marlow, Buckinghamshire, England
West Virginia Water Resources Commission

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ABSTRACT

In this study, 79 participating laboratories were instructed to dilute the provided concentrated water sample to a specified volume and analyze for nine specified metals. In their analyses for cadmium, lead, silver, and zinc, participants were instructed to use new methods to appear in the 12th edition of Standard Methods for the Examination of Water and Wastewater, which were provided with the sample.

Most participants preferred the aluminon method for determining aluminum, but their results indicated the method is not reliable. For copper analysis, the cuprethol method was the most popular, but the bathocuproine and zinc dibenzyl dithiocarbamate methods were more accurate. The most popular, accurate, and precise method for iron was 1, 10-phenanthroline. The use of persulfate to oxidize manganese to permanganate was chosen by the majority of participants and produced better accuracy and precision than the use of periodate. The new zinc procedure (same as mixed-color dithizone procedure in the 11th edition of Standard Methods) was satisfactory. Equal accuracy and precision was obtained for zinc by the zincon method. The dithizone method for silver was difficult, and better accuracy was obtained with instrumental techniques. The new cadmium procedure produced excellent accuracy and precision and was much less difficult than the present standard method in the 11th edition of Standard Methods. Diphenylcarbazide with oxidation by permanganate-azide was the procedure most widely used for determination of chromium and produced satisfactory results. The alkaline-hypobromite procedure for chromium was equally satisfactory. The new dithizone procedure for lead produced excellent results.

The few participants using atomic absorption spectroscopy achieved excellent results for all metals except aluminum, which was not measured by this method.

Use of the spectrograph produced good results for zinc and cadmium, but appeared less satisfactory for the analysis of aluminum, silver, chromium, lead, copper, iron, and manganese.

WATER METALS NO. 3

PURPOSE OF STUDY

This study (Water Metals No. 3) is similar in design to two previous studies conducted in 1957 and 1962. The decision to repeat this type of study was based on requests from many Analytical Reference Service members who wanted to compare individual laboratory results and to evaluate current procedures. In addition, the forthcoming 12th edition of Standard Methods for the Examination of Water and Wastewater will contain new analytical procedures, and this study provided an opportunity to evaluate the new methods for cadmium, lead, zinc, and silver. Also, newer instrumental techniques such as emission spectroscopy, atomic absorption spectroscopy, and polarography did not find extensive usage in the previous studies. It was hoped that this study would provide sufficient data for determining the precision and accuracy of these instrumental techniques.

DESIGN OF STUDY

The water sample was prepared as a concentrated solution to ensure greater stability of the sample and to reduce shipping costs. The solution was shipped in sterile JEB* sampling tubes and consisted of sterile, distilled, deionized water containing the following metallic compounds:

Compound	Metal	Metal, mg/l
$K_2Al_2(SO_4)_4 \cdot 24H_2O$	Al	100
Copper Metal	Cu	94
$Fe(NH_4)_2(SO_4)_2 \cdot 6H_2O$	Fe	60
$KMnO_4$	Mn	24
Zinc metal	Zn	130
$AgNO_3$	Ag	30
Cadmium metal	Cd	10
$K_2Cr_2O_7$	Cr	22
$Pb(NO_3)_2$	Pb	14

* Registered trade name for a vacuum sampling tube manufactured by Scientific Glass Company, Northfield, New Jersey.

The solid compounds were dissolved in nitric acid and excess acid was added to reduce the pH of the final mixture to below pH 1.0. The extreme acidity was expected to prevent precipitation and adsorption of the metals on the walls of the container. Repeated analyses in the ARS laboratory indicated that there was no change in a sample stored in a pyrex glass bottle.

Unfortunately, portions of the sample stored in JEB tubes were not initially studied, and as was later determined (see zinc and aluminum discussion), the high acidity of the sample apparently attacked the rubber stopper; this did have some effect upon the stability of the sample shipped in the JEB tubes. In fact, many participants commented that the sample was clear when received, but after some of the sample had been removed from the JEB tube, small reddish particles appeared in the sample. The protective coating on the rubber stopper undoubtedly deteriorated as a result of the high acidity, and the stopper crumbled when the tube was opened to remove the sample. Since before analysis the participants were instructed to dilute 5 ml of the sample to 1 liter, the rubber particles by themselves should not have caused any difficulty, but as will be discussed later, some dissolved material from the rubber stopper was apparently also present.

The participants were requested to use the procedures sent with the sample for the analysis of zinc, silver, cadmium and lead. These procedures were those which have now been published in the 12th edition of Standard Methods for the Examination of Water and Wastewater. They contained two methods for silver (dithizone and spectrographic), three for zinc (dithizone, zincon and polarographic), and one each for cadmium (dithizone) and lead (dithizone). It was suggested in each case that the participant use the dithizone method, and not try to analyze the sample by all of the methods. In the case of the remaining metals, it was suggested that the participants use the methods regularly employed in their laboratories.

TREATMENT OF DATA

Seventy-nine participating agencies reported a total of 1,599 analytical results based on measurements made in triplicate. The mean of the results reported by each participant was plotted on probability paper to determine the distribution. Values showing a gross deviation from the normal distribution line were rejected as nonrepresentative because of errors in calculation, dilution, or other indeterminate factors. The rejected values are circled on the probability plot. These rejected values were not included in any of the statistical computations. In instances where a mathematical error was suspected, the reporting laboratory was asked to review the calculations and to submit corrected values if an error was found.

The results of one laboratory (9713) were excluded throughout this report because an error was made in diluting the sample for analysis and it was not possible to correct results accordingly.

The calculation of a standard deviation for a method was based on the difference between the average result obtained by each participant and the mean of all the values reported by each participant using the method. The average reported values were also used in the bar charts and statistical summary. The various procedures were grouped according to the basic reactions, and slight modifications in technique were not considered in the evaluation.

Since the instruction sheet included a request that results be reported to the nearest hundredth milligram per liter, values reported to three or four decimal places were rounded off for uniformity, according to the rule published in Standard Methods for the Examination of Water and Wastewater.

Results of analyses for each of the metals performed by the participating laboratories are tabulated in the appendices.

DISCUSSION

ALUMINUM, 0.50 mg/l (Table 1, Figures 1 and 2).

Ten different methods were used to measure aluminum, but only two were used by enough participants to permit statistical evaluation. The other eight methods were used by only one laboratory each. Forty-four values were obtained by use of the aluminon procedure, not including one outlier. The results ranged from 0.00 to 0.81 with a mean of 0.40 mg/l and a standard deviation of 0.153. The accuracy and precision are essentially the same as in the previous study of this type, which showed a deviation for the mean of 23% from the amount added and a standard deviation of 0.137. The mean was high in the previous study, whereas in the present study the mean is 20% low.

The low results in this study seem unusual, and although no ready explanation is available, the results do indicate that further study of the method is needed. One possible explanation is that the determination is not linear over all ranges of concentration; namely, high results may be obtained at high concentrations and low results at low concentrations of aluminum. In this study another possibility is that some dissolved substances from the rubber stopper of the JEB tube interferred (see zinc discussion). Both of these possibilities were investigated by ARS, however, and no correlation seemed evident in either case.

The four values obtained with the spectrograph exhibit somewhat better precision than the aluminon method, as indicated by the standard deviation of 0.091, but the accuracy is poorer according to the mean of 0.235. One gravimetric result of 1.48 mg/l was rejected as an outlier.

On the basis of the results of this study, the aluminon procedure appears to be the most accurate, but the need for a more reliable method is evident.

GPO 826-233-2

Table 1. SUMMARY OF DATA ON ALUMINUM
(0.50 mg/l added to water sample)

Method	Number of results	Mean	Median	Minimum	Maximum	50% Range	Standard deviation	95% Confidence limits of the mean
Aluminon	44[a]	0.400	0.370	0.00	0.81	±0.14	0.153	0.400 ± 0.047
Spectrograph	4	0.235	0.270	0.10	0.30	±0.23	0.091	0.235 ± 0.145
8-Hydroxyquinone	1	0.780	-----	----	----	-----	-----	------
Haematoxylin	1	0.380	-----	----	----	-----	-----	------
Cyanine R	1	0.240	-----	----	----	-----	-----	------
Alizarin red S	1	0.360	-----	----	----	-----	-----	------
Fluorometric	1	0.190	-----	----	----	-----	-----	------
Gravimetric	1			(Rejected)				
Ferroin	1	0.290	-----	----	----	-----	-----	------
Eriochrome cyanine R	1	0.310	-----	----	----	-----	-----	------
Overall	55[a]	0.384	0.360	0.00	0.81	±0.16	0.159	0.384 ± 0.043

[a] Does not include one outlier.

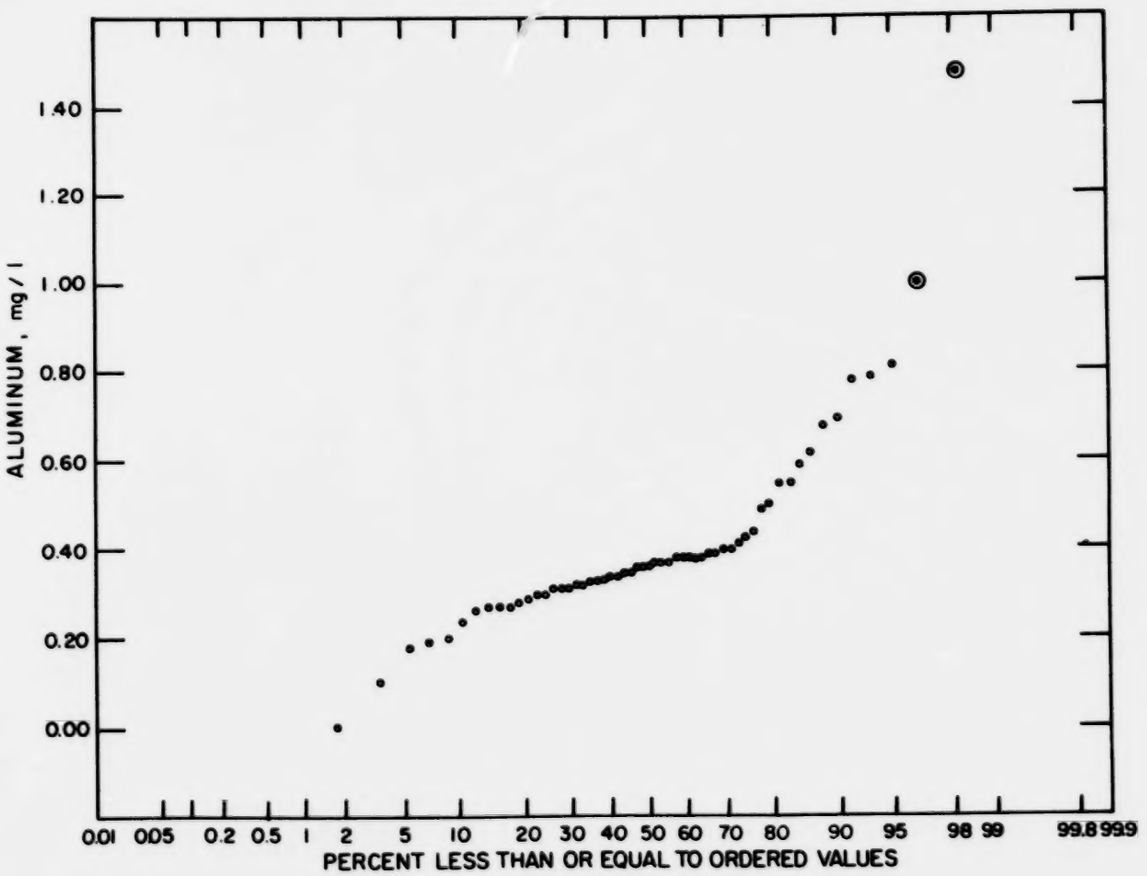

Figure 1. Probability curve for aluminum.

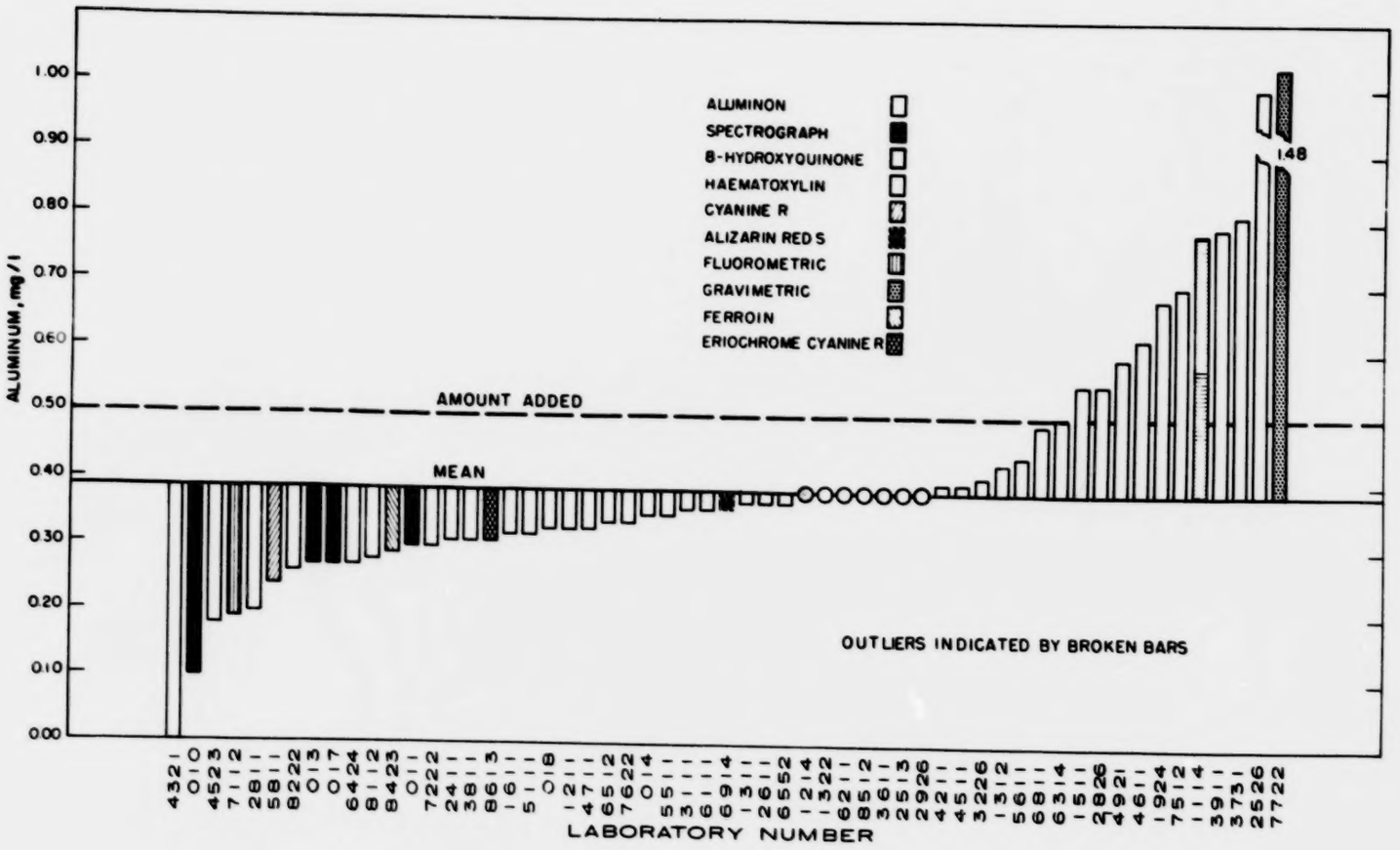

Figure 2. Bar graph for aluminum.

COPPER, 0.47 mg/l (Table 2, Figures 3 and 4).

Copper is one of the more commonly measured heavy metals. The 65 laboratories that reported the copper analysis used 9 different procedures. The most popular was the "cuprethol" procedure, which was used by 25 participants. The results with this method tended to be a little high according to the mean of 0.51 mg/l, and the precision as shown by the standard deviation of 0.090, was poorer than that for any method except polarography. The best results were produced by the "bathocuproine" procedure, which was used by 7 participants. The mean was 0.47, equal to the amount added, and the standard deviation was 0.021. The 50% range shows that at least half of the results obtained by use of this method indicated amounts equal to the amount added. Atomic absorption produced essentially the same accuracy and precision, as did the zinc dibenzyl dithiocarbamate colorimetric procedure. The spectrograph, which was used by three participants, produced low results.

The overall performance indicates that analysis for copper presents little difficulty to the average analyst.

Table 2. SUMMARY OF DATA ON COPPER
(0.47 mg/l added to water sample)

Method	Number of results	Mean	Median	Minimum	Maximum	50% Range	Standard deviation	95% Confidence limits of the mean
Cuprethol	25	0.514	0.500	0.26	0.72	±0.03	0.090	0.514±0.037
Sodium Diethyldithiocarbamate	12	0.495	0.500	0.40	0.63	±0.03	0.058	0.495±0.037
Bathocuproine	7	0.470	0.470	0.44	0.51	±0.00	0.021	0.470±0.019
Neocuproine	6	0.448	0.470	0.31	0.53	±0.03	0.079	0.448±0.083
Zinc dibenzyldithiocarbamate	4	0.460	0.460	0.44	0.48	±0.01	0.016	0.460±0.026
Spectrograph	3	0.400	0.390	0.35	0.46	±0.08	0.056	0.400±0.139
Atomic absorption	3	0.477	0.470	0.47	0.49	±0.00	0.011	0.477±0.028
Polarograph	3[a]	0.557	0.500	0.47	0.70	±0.03	0.125	0.557±0.311
Unspecified	2	0.425	0.425	0.37	0.48	±0.01	0.078	------
Bis (cyclohexanon)-oxaldihydrazon	1	0.290	-----	----	----	-----	-----	------
Overall	66[a]	0.478	0.480	0.26	0.72	±0.03	0.079	0.485±0.009

[a] Does not include one outlier.

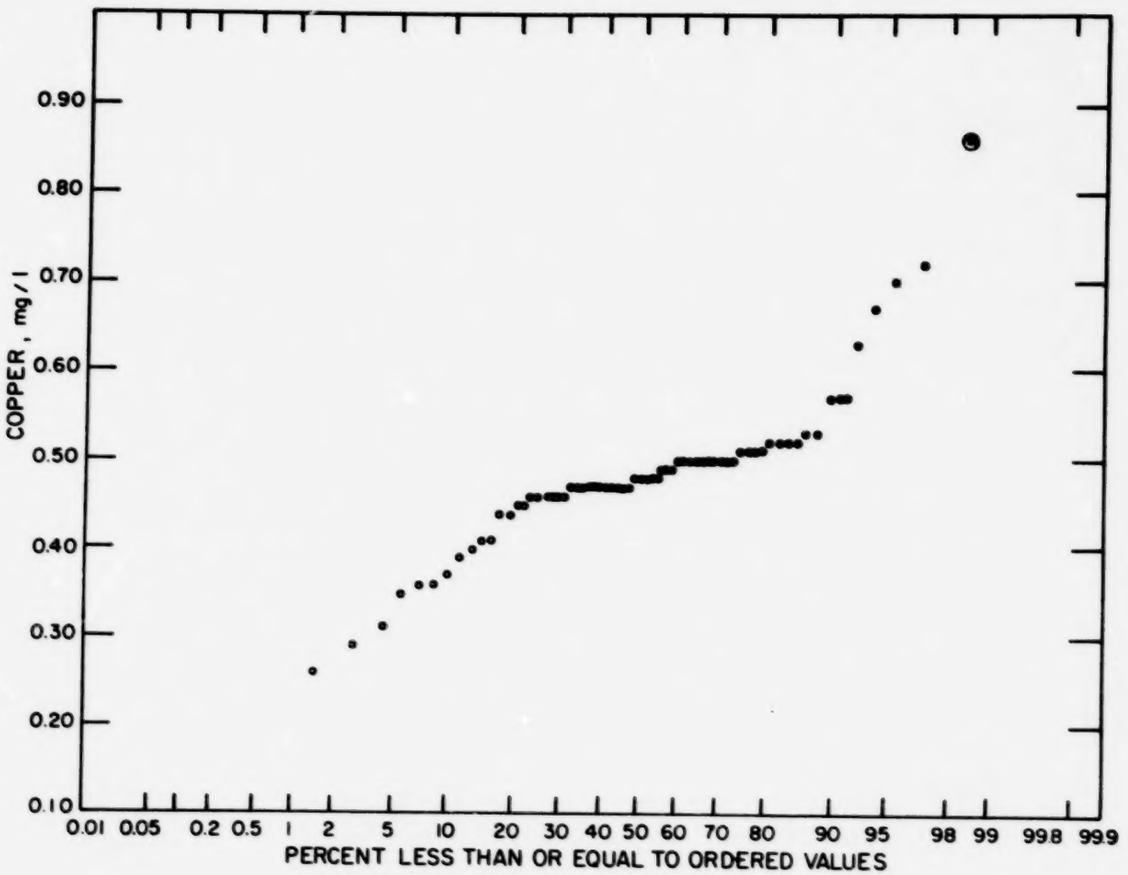

Figure 3. Probability curve for copper.

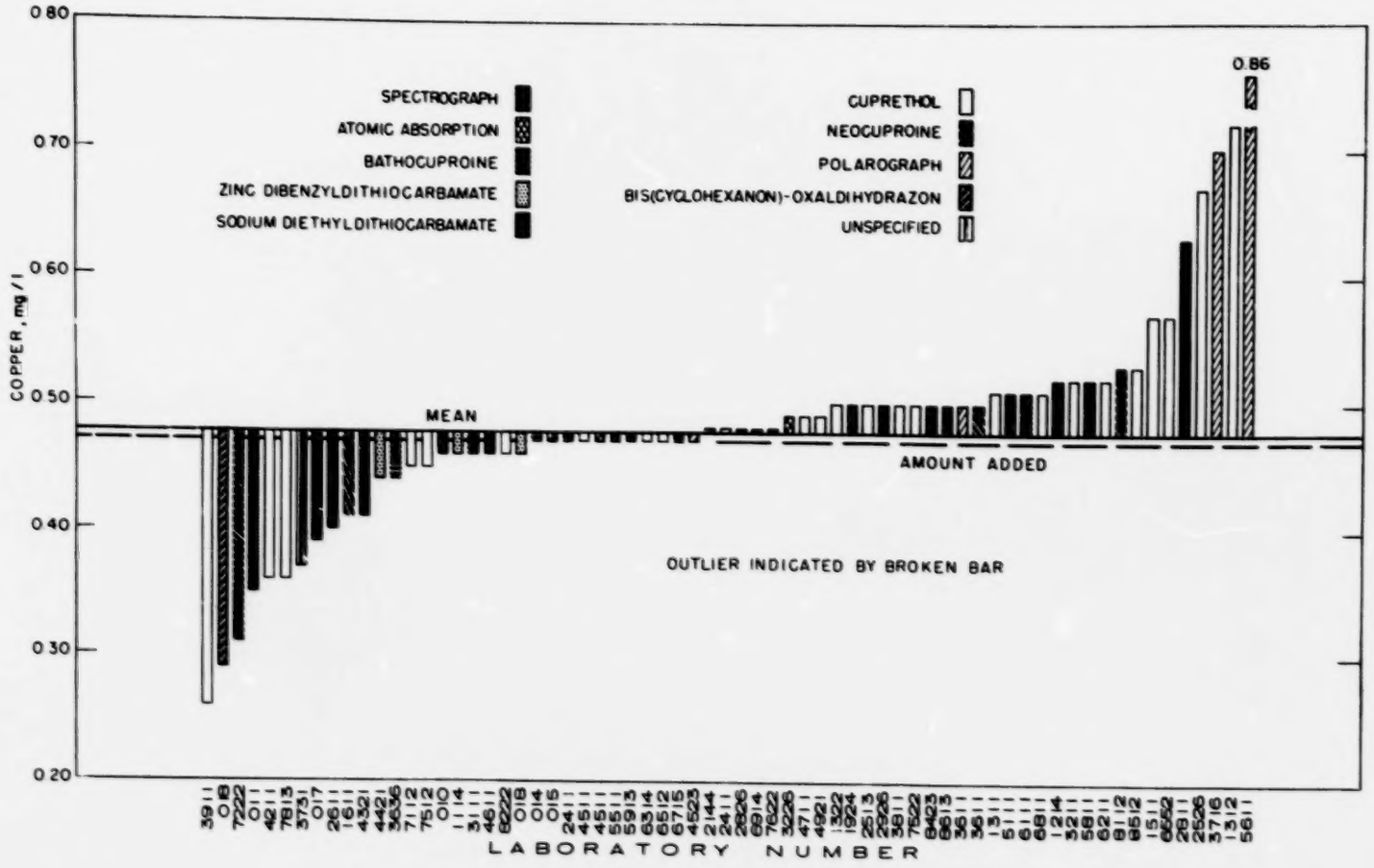

Figure 4. Bar graph for copper.

IRON, 0.30 mg/l (Table 3, Figures 5 and 6).

Ten different methods were employed to measure iron. The most popular was the orthophenanthroline procedure used by 40 participants. The tendency was toward slightly high results with a mean value of 0.337 mg/l and a standard deviation of 0.086. The 50% range shows, however, that the better half of the results were within $\pm$0.02 mg/l of the amount added. The thiocyanate procedure was employed by 11 participants and produced even higher results with the same degree of precision. The tripyridine method produced low results and poor precision. The results obtained with the spectrograph and atomic absorption showed nearly the same precision as 1, 10-phenanthroline and slightly better accuracy. The overall mean for all methods was 0.326 mg/l and the 50% range was $\pm$0.03.

According to a special spectrographic analysis, the rubber stopper for the sample tube contained 24 mg of iron per gram of rubber. This might possibly account for some of the higher values, but the increase could not have been very great according to the generally excellent results.

Table 3. SUMMARY OF DATA ON IRON
(0.30 mg/l added to water sample)

Method	Number of results	Mean	Median	Minimum	Maximum	50% Range	Standard deviation	95% Confidence limits of the mean
1, 10-Phenanthroline	40	0.337	0.310	0.08	0.53	±0.02	0.086	0.337 ± 0.026
Thiocyanate	11	0.352	0.350	0.22	0.53	±0.05	0.085	0.352 ± 0.057
Tripyridine	6[a]	0.260	0.290	0.03	0.45	±0.09	0.162	0.260 ± 0.170
Spectrograph	5	0.280	0.320	0.12	0.33	±0.03	0.090	0.280 ± 0.110
Bathophenanthroline	3	0.327	0.330	0.32	0.33	±0.03	0.006	0.327 ± 0.011
Atomic absorption	2	0.295	0.295	0.24	0.35	±0.05	0.078	------
α, α'-Dipyridyl	2	0.325	0.325	0.32	0.33	±0.02	0.006	------
Bipyridine	2	0.325	0.325	0.32	0.33	±0.02	0.006	------
Thioglycolic acid	1[a]	0.250	-----	----	----	-----	-----	------
2, 4, 6-Tripyridyl-S-triazine	1	0.410	-----	----	----	-----	-----	------
Overall	73[b]	0.326	0.320	0.03	0.53	±0.03	0.091	0.326 ± 0.021

[a] Does not include one outlier.
[b] Does not include two outliers.

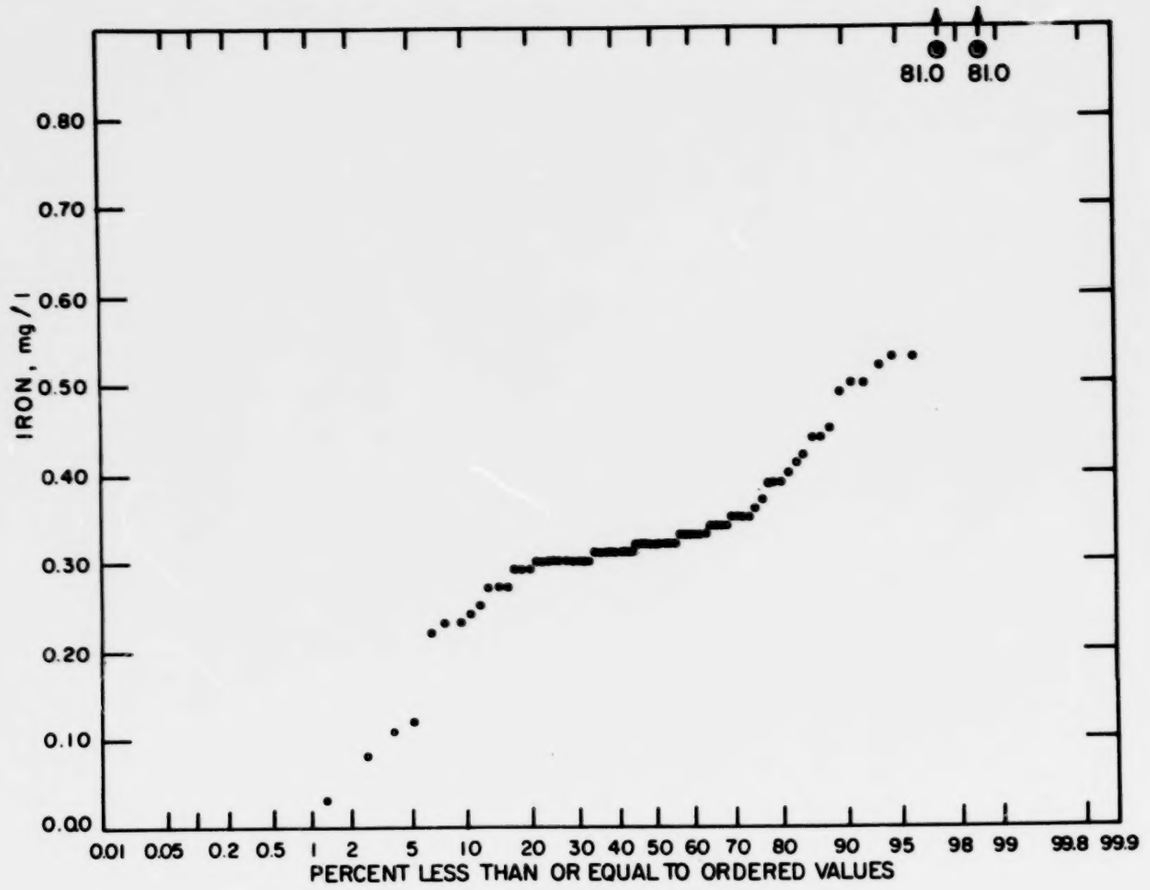

Figure 5. Probability curve for iron.

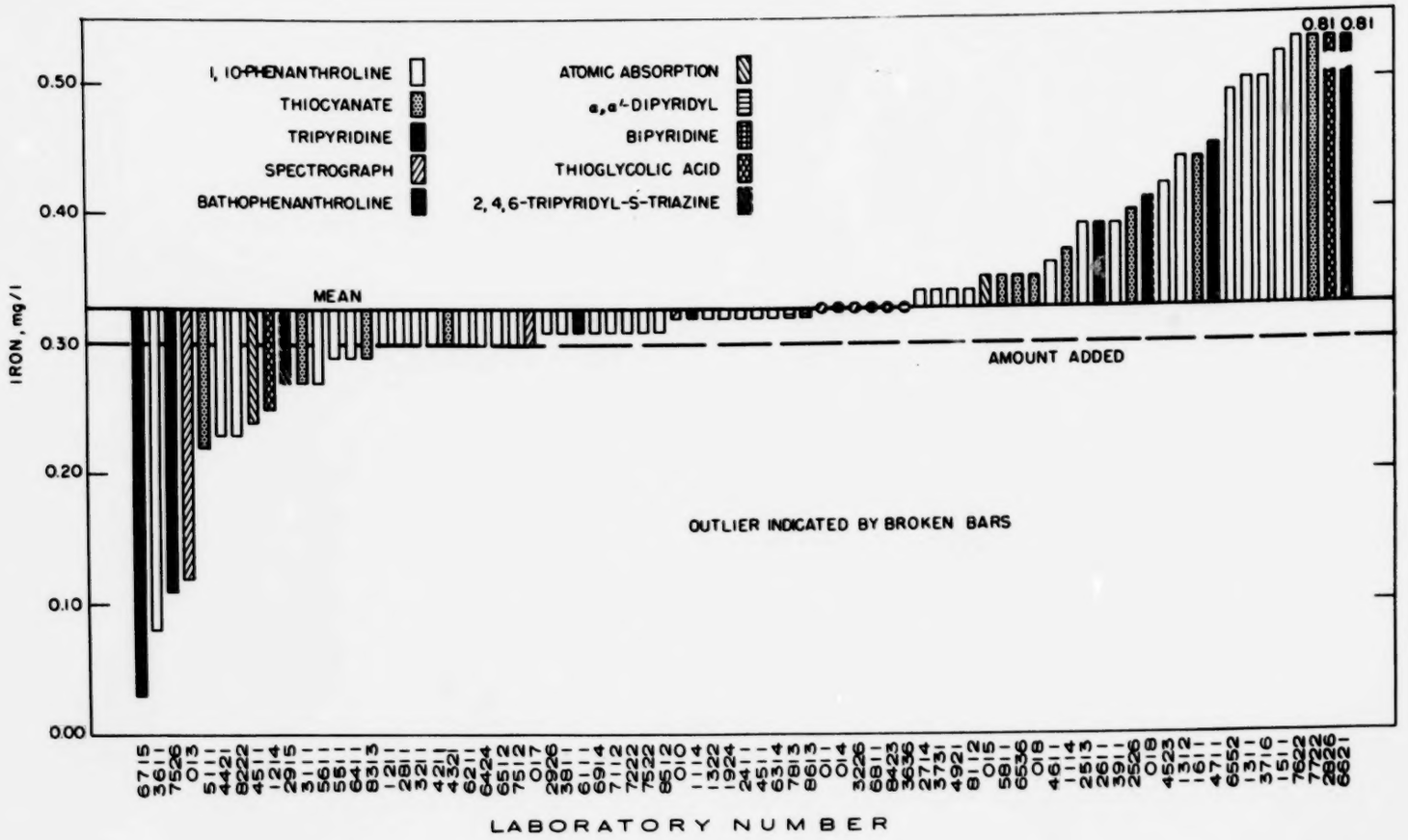

Figure 6. Bar graph for iron.

MANGANESE, 0.12 mg/l (Table 4, Figures 7 and 8).

Of the 61 agencies that performed this analysis, 49 used a colorimetric procedure consisting of oxidation of soluble manganous compounds to permanganate. The majority employed persulfate as the oxidant; this produced better accuracy and precision than periodate. Three participants used atomic absorption and four used the spectrograph; both produced equally accurate and precise results. The use of formaldoxime produced the most inaccurate results although two out of the three results obtained by this method were within 0.02 mg/l of the amount added. This value is also the 50% range for the spectrograph, persulfate, and atomic absorption procedures.

The overall results indicate that any of the methods used should produce good results if properly performed but that persulfate is preferable to periodate as the oxidant.

Table 4. SUMMARY OF DATA ON MANGANESE
(0.12 mg/l added to water sample)

Method	Number of results	Mean	Median	Minimum	Maximum	50% Range	Standard deviation	95% Confidence limits of the mean
Persulfate	33[a]	0.118	0.120	0.03	0.21	±0.01	0.031	0.118±0.011
Periodate	14	0.150	0.155	0.04	0.26	±0.04	0.054	0.150±0.031
Spectrograph	4	0.113	0.110	0.09	0.14	±0.02	0.022	0.113±0.035
Atomic absorption	3	0.127	0.130	0.10	0.15	±0.02	0.025	0.127±0.063
Formaldoxime	3	0.180	0.140	0.14	0.26	±0.02	0.069	0.180±0.171
Tetrabase	1	0.050	-----	----	----	-----	-----	------
Unspecified	1	0.000	-----	----	----	-----	-----	------
Overall	59[a]	0.125	0.120	0.00	0.21	±0.02	0.059	0.125±0.012

[a] Does not include three outliers.

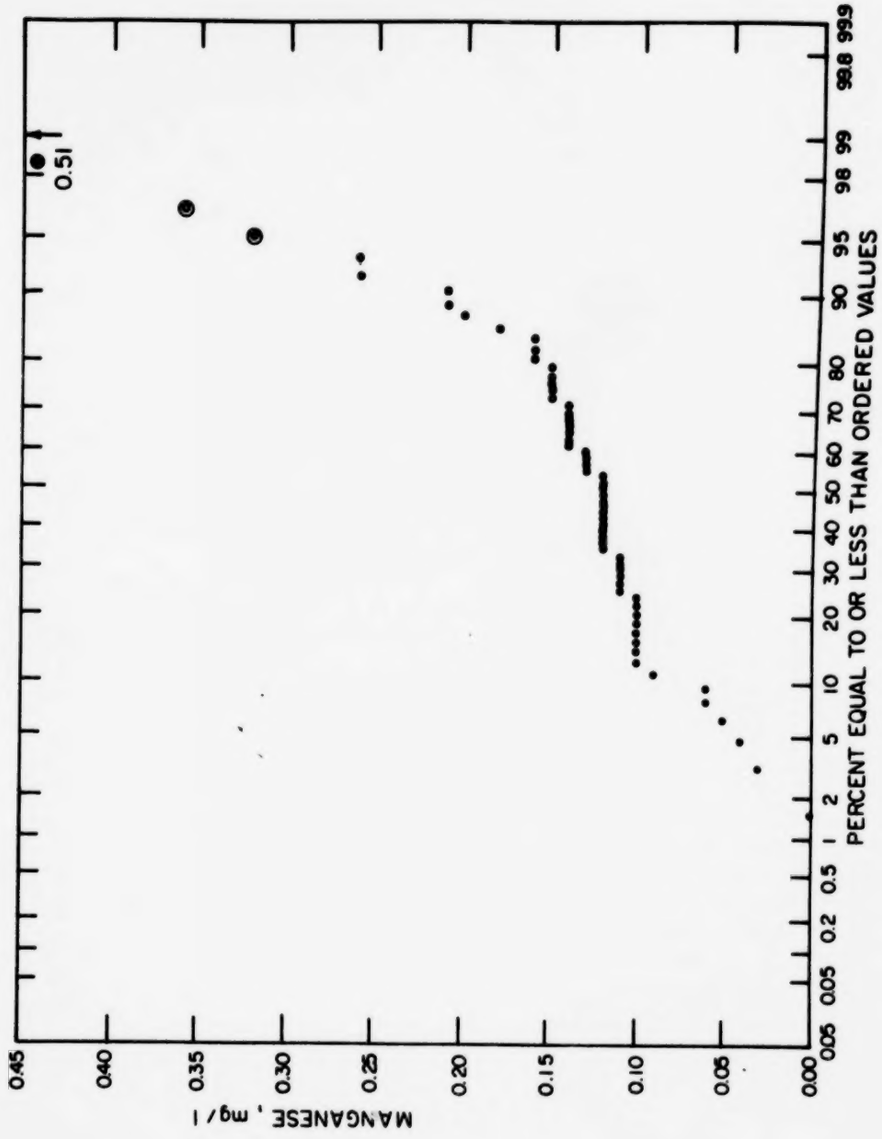

Figure 7. Probability curve for manganese.

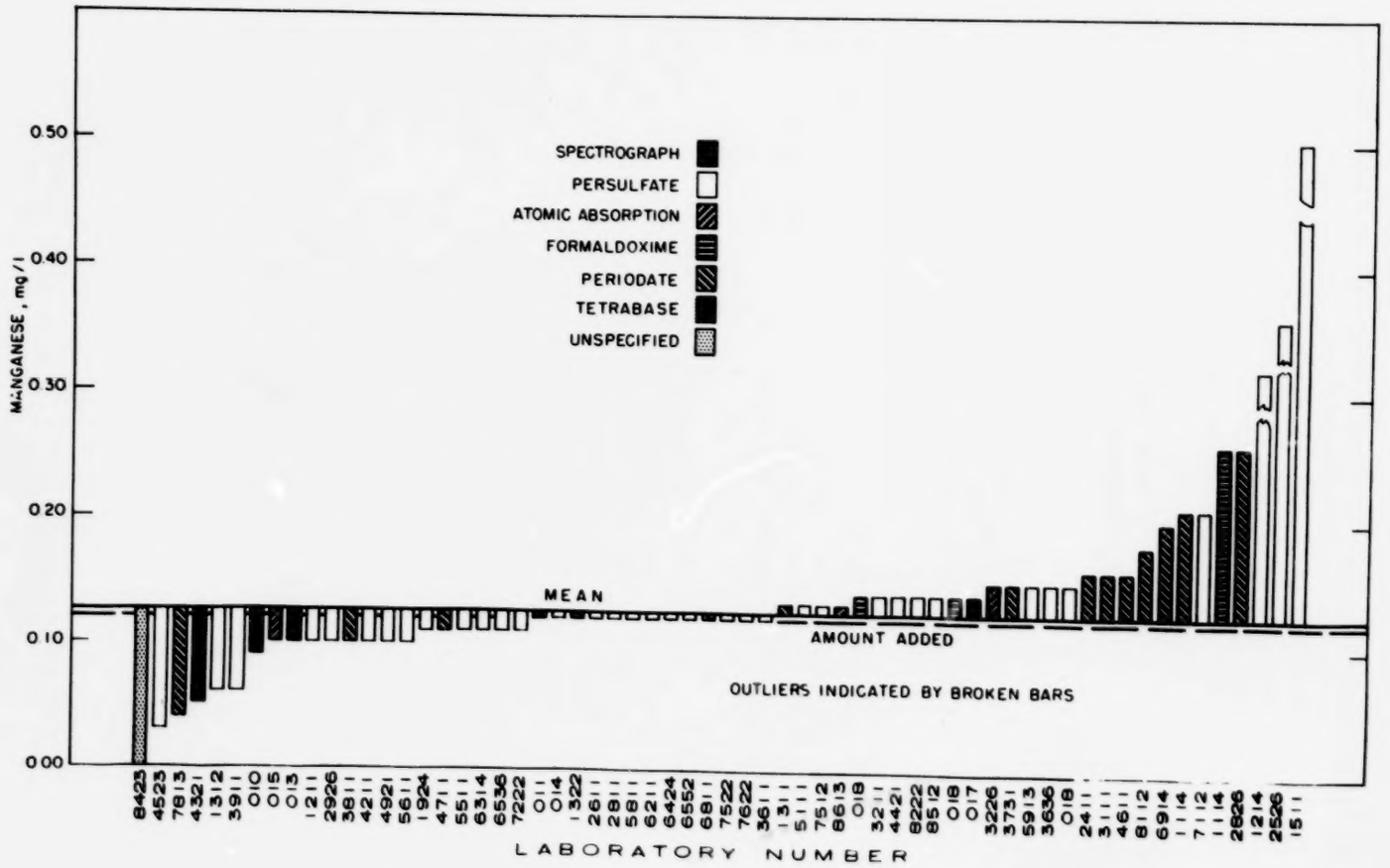

Figure 8. Bar graph for manganese.

ZINC, 0.65 mg/l (Table 5, Figures 9 and 10).

All zinc results showed a tendency to be a little high. Frequent analyses of the sample solution stored in a pyrex glass bottle showed no deviation from the theoretical amount added, but further investigation disclosed that a substantial amount of zinc was leached from the rubber stopper of the JEB tube in which the sample was shipped. The amount of contamination was indeterminate because of the variables involved, such as the position in which the tube was stored and the length of time that the solution was in contact with the rubber stopper. Accuracy and precision values, therefore, are questionable, but the results indicate that all methods used should produce satisfactory results for routine analyses. So few participants used the instrumental methods such as polarography, atomic absorption spectrophotometry, and emission spectroscopy that statistical parameters have a low confidence level. The results obtained by these techniques, nevertheless, showed no substantial difference from the results produced by the dithizone procedure which had been provided. Most participants who commented on the dithizone procedure said they experienced no difficulty in performing the analysis. Since this procedure is the same as the mixed-color procedure in Part I of the 11th edition of Standard Methods, many participants undoubtedly were familiar with the method.

The amount of zinc added to the sample was 0.65 mg/l, but the mean of all analyses indicated the presence of 0.82 mg/l. Atomic absorption spectroscopy produced a mean value of 0.78 mg/l, which was nearest the amount added, whereas polarography produced a mean value of 0.92 mg/l, which was the highest value measured by any method.

The dithizone results have the greatest significance since the method was used by 46 participants. The mean was 0.82 mg/l and the standard deviation, 0.149. The 95% confidence limits were $\pm$0.044.

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Table 5. SUMMARY OF DATA ON ZINC
(0.65 mg/l added to water sample)

Method	Number of results	Mean	Median	Minimum	Maximum	50% Range	Standard deviation	95% Confidence limits of the mean
Dithizone[a]	46	0.818	0.800	0.34	1.30	±0.15	0.149	0.818±0.044
Dithizone, unspecified	6	0.793	0.760	0.60	1.05	±0.11	0.153	0.793±0.161
Polarograph, unspecified	6	0.917	0.900	0.86	0.99	±0.26	0.046	0.917±0.048
Zincon[a]	4	0.763	0.773	0.63	0.87	±0.08	0.106	0.762±0.169
Spectrograph	3	0.817	0.820	0.67	0.96	±0.17	0.145	0.817±0.360
Atomic absorption	3	0.777	0.800	0.75	0.80	±0.13	0.025	0.777±0.062
Polarograph[a]	2	0.915	0.915	0.73	1.10	±0.08	0.262	------
Zincon, unspecified	2	0.895	0.895	0.79	1.00	±0.14	0.149	------
Overall	72	0.824	0.800	0.34	1.30	±0.16	0.140	0.824±0.033

[a] Copies of instructions provided with sample.

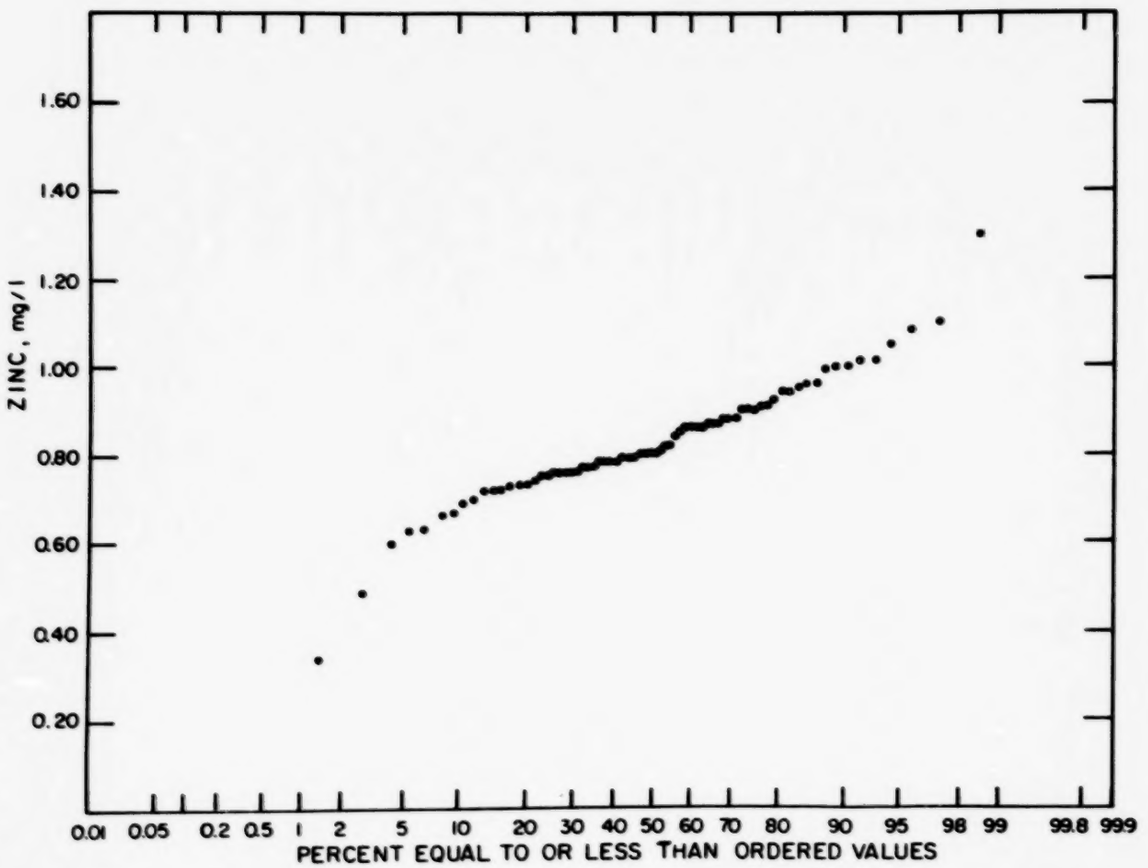

Figure 9. Probability curve for zinc.

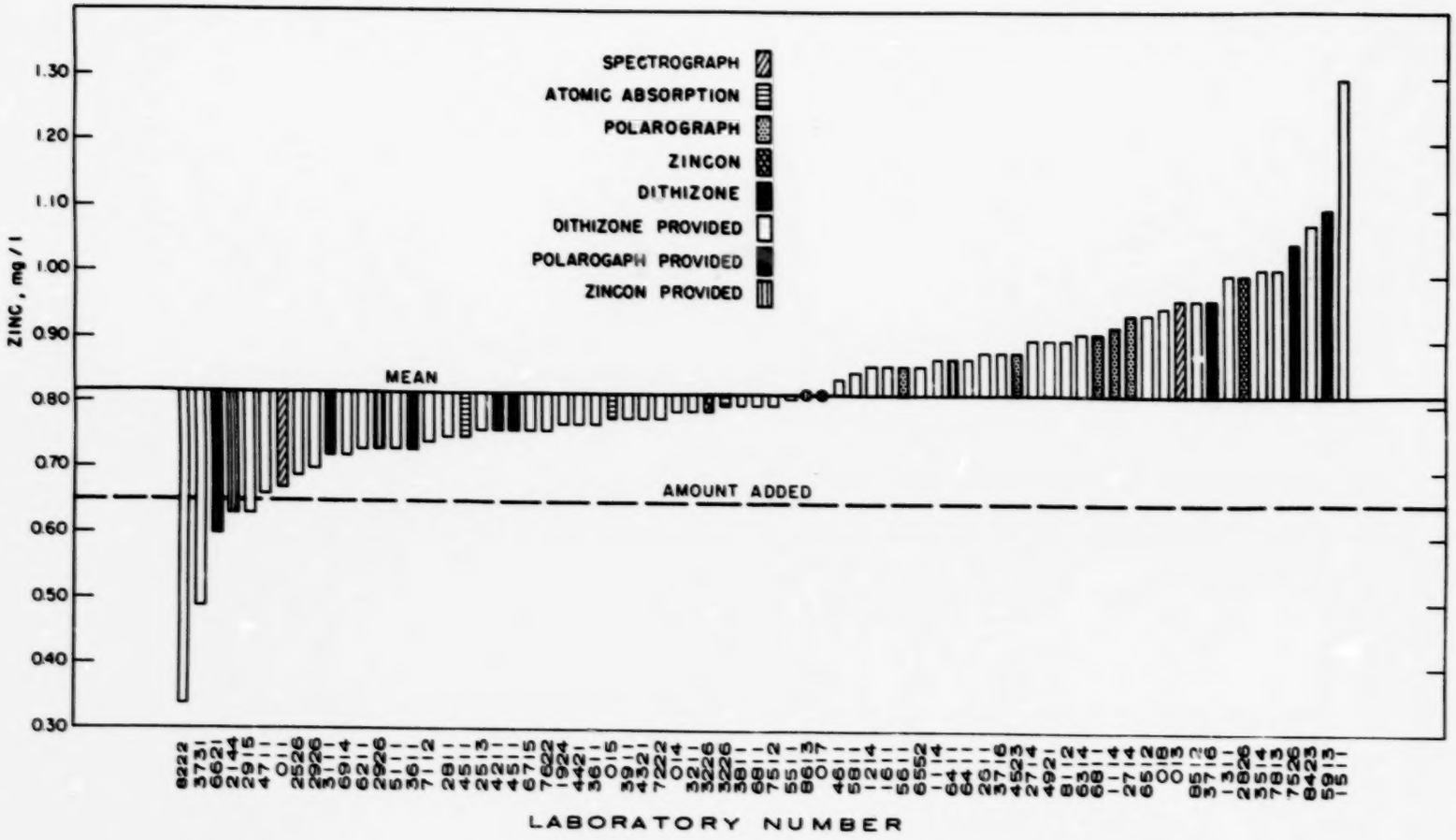

Figure 10. Bar graph for zinc.

SILVER, 0.15 mg/l (Table 6, Figures 11 and 12).

This is the first reference sample to include silver for analysis. A number of sensitive procedures are available for its measurement in water. Most of these methods are subject to numerous interferences and require great care and attention to detail to obtain accurate results. The greatest problem is the loss of silver that may occur through adsorption on the walls of the sample container, and glassware used in the analytical procedure. For this reason, the expected tendency would be toward low results, although incomplete removal of interferences could produce high results in the dithizone or other colorimetric procedures.

The results of this study indicate on overwhelming tendency toward low results from all methods except atomic absorption spectroscopy. Only two participants used this technique. One obtained a value of 0.11 mg/l and the other, 0.24 mg/l.

The spectrograph was used by three participants. One of the results was 0.15 mg/l, the theoretical value; another was 0.10 mg/l, which is more accurate than the mean of the dithizone results; and the third was 0.02 mg/l. The 0.02 mg/l value may have resulted from an error in technique or calculation. These results indicate that with careful technique, the spectrograph can successfully be used to measure silver at the concentration provided in the sample.

The dithizone procedure appears to be the least desirable method because of the amount of glassware requiring special handling and because of the difficulties encountered in evaporating the sample to dryness.

Table 6. SUMMARY OF DATA ON SILVER
(0.15 mg/l added to water sample)

Method	Number of results	Mean	Median	Minimum	Maximum	50% Range	Standard deviation	95% Confidence limits of the mean
Dithizone[a]	14[b]	0.049	0.050	0.00	0.10	±0.10	0.030	0.049 ± 0.017
Spectrograph	3	0.090	0.100	0.02	0.15	±0.05	0.066	0.090 ± 0.164
Atomic absorption	1[b]	0.110	-----	----	----	-----	0.000	------
Dithizone, unspecified	1[b]	0.150	-----	----	----	-----	0.000	------
Spectrograph[a]	1	0.110	-----	----	----	-----	-----	------
Overall	20[c]	0.066	0.060	0.00	0.15	±0.09	0.044	0.066 ± 0.021

[a] Copies of instructions provided with sample.
[b] Does not include one outlier.
[c] Does not include three outliers.

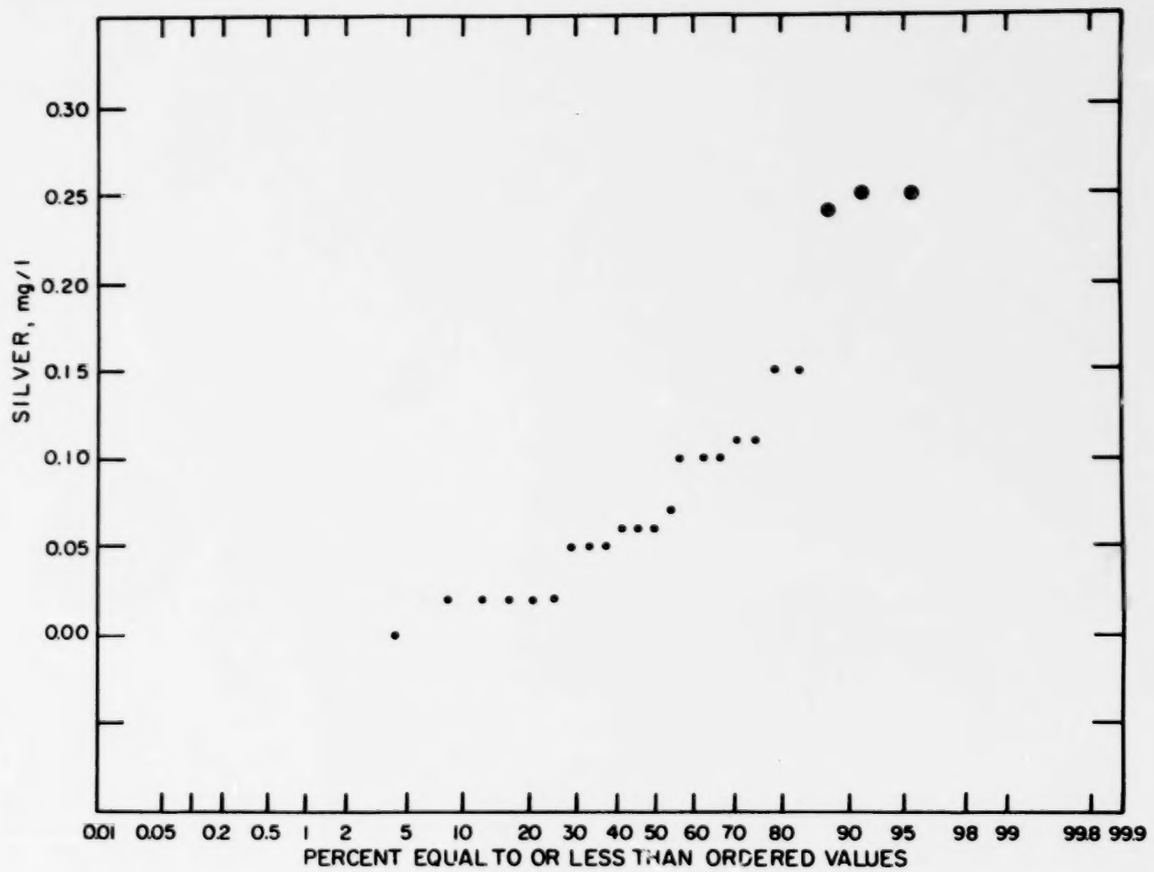

Figure 11. Probability curve for silver.

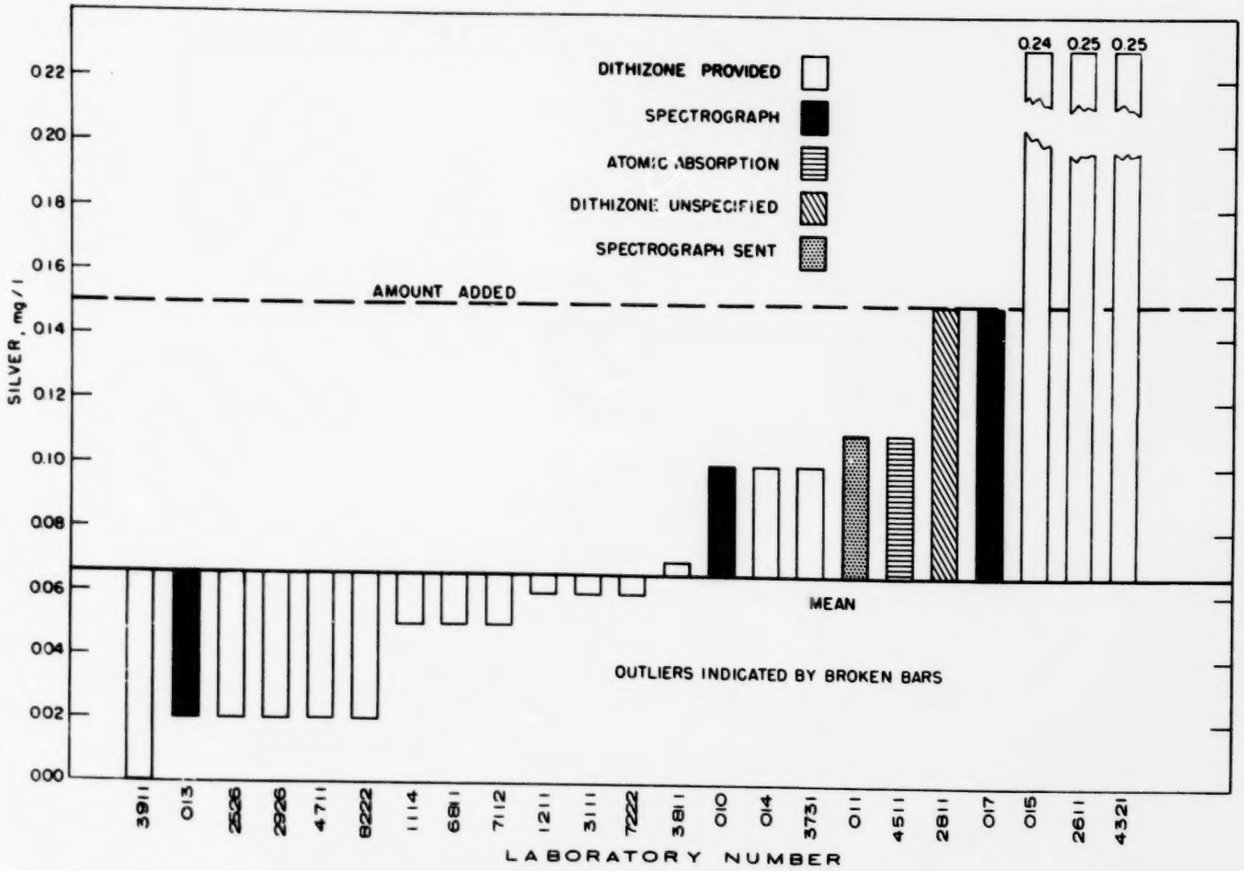

Figure 12. Bar graph for silver.

CADMIUM, 0.05 mg/l (Table 7, Figures 13 and 14).

The measurement of cadmium is generally considered the most difficult of the dithizone procedures to use.

Of the 54 participants who reported this determination, 44 used the provided dithizone procedure with generally excellent results. The mean was 0.053 mg/l and the standard deviation was 0.013. At least half reported 0.05 mg/l, the amount added. The two participants who used the spectrograph achieved a similar degree of accuracy and precision with a mean of 0.051 mg/l and a standard deviation of 0.007. The two results obtained by use of atomic absorption both agreed with the amount added. The polarograph made the poorest showing; one value was rejected, and the other four provided a mean of 0.040 mg/l and a standard deviation of 0.034.

No difficulty was encountered, and the general opinion was that the dithizone procedure was preferable to the procedure in the 11th edition of Standard Methods.

Table 7. SUMMARY OF DATA ON CADMIUM
(0.05 mg/l added to water sample)

Method	Number of results	Mean	Median	Minimum	Maximum	50% Range	Standard deviation	95% Confidence limits of the mean
Dithizone[a]	44[b]	0.053	0.050	0.02	0.11	±0.00	0.013	0.053 ± 0.004
Polarograph	4[c]	0.040	0.040	0.00	0.08	±0.02	0.034	------
Dithizone, unspecified	2	0.035	0.035	0.02	0.05	±0.00	0.021	------
Spectrograph	2	0.051	0.055	0.05	0.06	±0.00	0.007	------
Atomic absorption	2	0.050	0.050	0.05	0.05	±0.00	0.000	------
Overall	54[d]	0.051	0.050	0.00	0.11	±0.00	0.016	0.051 ± 0.004

[a] Copies of instructions provided with sample.
[b] Does not include two outliers.
[c] Does not include one outlier.
[d] Does not include three outliers

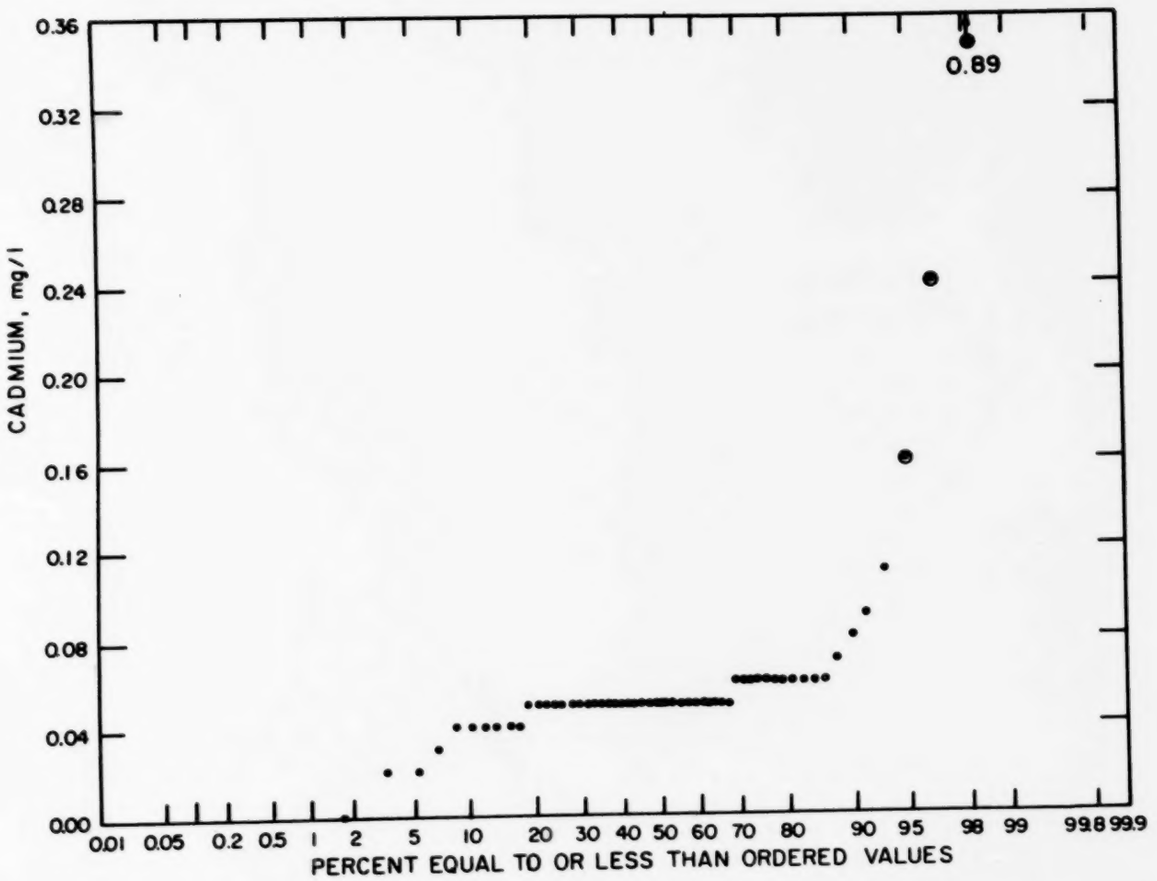

Figure 13. Probability curve for cadmium.

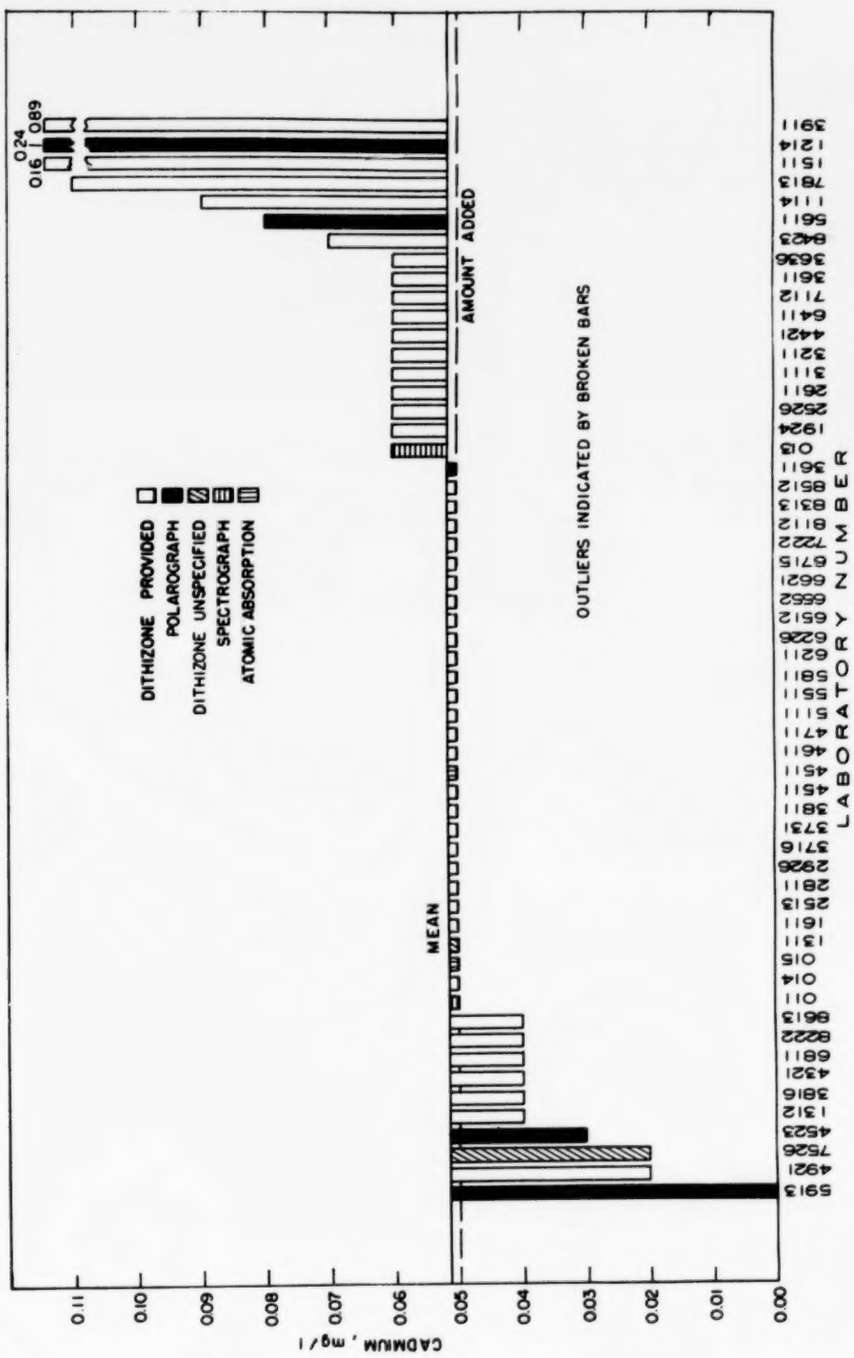

Figure 14. Bar graph for cadmium.

CHROMIUM, 0.11 mg/l (Table 8, Figures 15 and 16).

Of the 57 participants who submitted a chromium measurement, 8 used an instrumental technique and the rest used a colorimetric procedure involving diphenylcarbazide. Information about the procedure employed was not always as complete as desired, but five participants evidently measured only hexavalent chromium and obtained extremely low values. The most popular method was the permanganate-azide oxidation used by 31 participants. The results were a little low with a mean of 0.092 mg/l and a standard deviation of 0.044. The alkaline hypobromite oxidation used by seven participants produced almost similar accuracy with a mean of 0.089 mg/l, and slightly better precision with a standard deviation of 0.023. Also, the more accurate half of the results deviated from the amount added by only 0.01 mg/l. The spectrograph, which tended to produce high results, exhibited the poorest accuracy and precision.

Because of the conditions present in the sample, most of the chromium was evidently reduced to the trivalent form, which required an oxidation procedure to measure total chromium. Incomplete oxidation, therefore, seems a likely explanation for the tendency toward slightly low results.

The overall performance indicates that any of the methods for analysis of total chromium used by more than one participant is capable of producing good accuracy since the more accurate half of the results from each method were within $\pm$0.02 mg/l of the amount added.

Table 8. SUMMARY OF DATA ON CHROMIUM
(0.11 mg/l added to water sample)

Method	Number of results	Mean	Median	Minimum	Maximum	50% Range	Standard deviation	95% Confidence limits of the mean
Diphenylcarbazide + permanganate-azide	31	0.092	0.090	0.00	0.21	±0.02	0.044	0.092±0.016
Diphenylcarbazide+alk.-hypobromite	7	0.089	0.100	0.05	0.12	±0.01	0.023	0.089±0.021
Diphenylcarbazide hexavalent chromium	5	0.010	0.010	0.00	0.03	±0.10	0.012	0.010±0.015
Diphenylcarbazide, unspecified	4	0.098	0.105	0.06	0.12	±0.01	0.028	0.098±0.045
Spectrograph	4	0.145	0.150	0.09	0.19	±0.02	0.053	0.145±0.097
Polarograph	3	0.130	0.130	0.11	0.15	±0.02	0.020	0.130±0.037
Diphenylcarbazide + silver perioxide	1	0.060	-----	----	----	-----	-----	------
Atomic absorption	1	0.100	-----	----	----	-----	-----	------
Diphenylcarbazide trivalent chromium	1	0.100	-----	----	----	-----	-----	------
Overall	57	0.090	0.100	0.00	0.21	±0.02	0.047	0.090±0.012

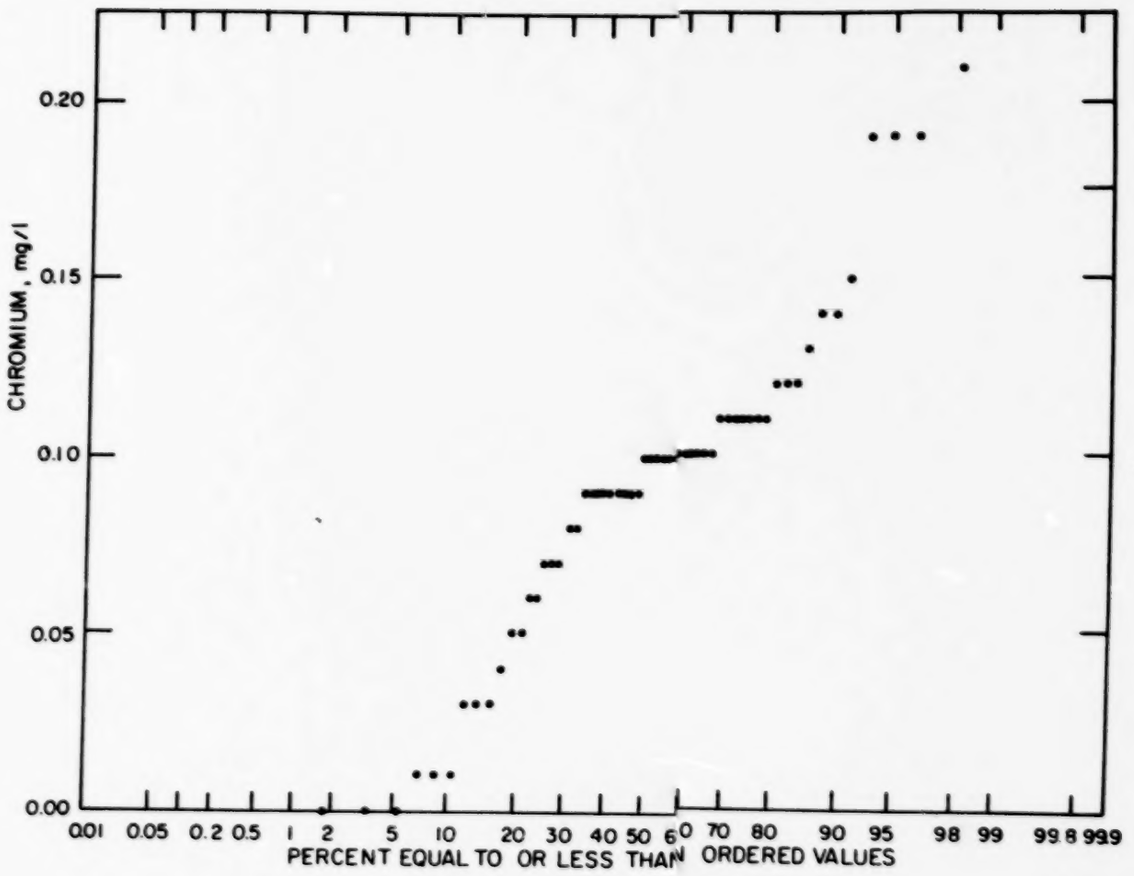

Figure 15. Probability curve for chromium.

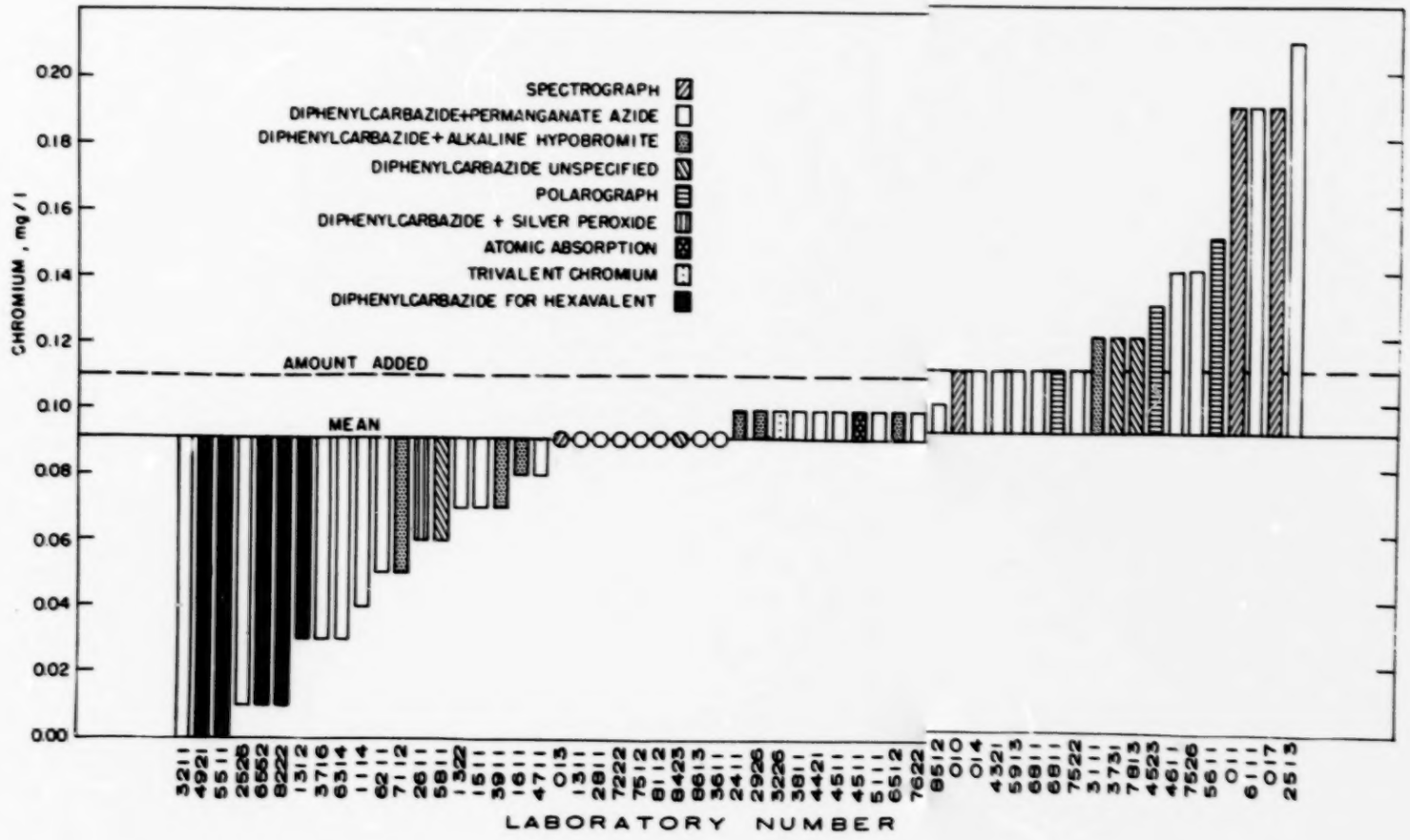

Figure 16. Bar graph for chromium.

LEAD, 0.07 mg/l (Table 9, Figures 17 and 18).

Overall, the lead analyses were excellent. The more accurate half of all results were within $\pm$ 0.01 mg/l of the amount added regardless of method used.

The dithizone procedure, provided to the participants with the sample, produced a mean value of 0.076 mg/l and a standard deviation of 0.032. Two values obtained by use of atomic absorption spectroscopy produced a mean of 0.085 mg/l and a standard deviation of 0.007. The spectrograph, used by three participants, showed a little less accuracy and precision, with a mean of 0.093 mg/l and a standard deviation of 0.058. Polarography showed a tendency toward high results: one very high result was rejected; another was 0.14 mg/l; and a third was 0.07 mg/l, the amount added.

In spite of the numerous comments concerning the difficulties encountered in washing the cyanide solution with dithizone and the adjustment of pH, the results show a high degree of accuracy and precision, when the low concentration of lead present is considered. The dithizone procedure might be improved if further investigation shows that it would be preferable to eliminate the dithizone wash of the cyanide solution and rely on the reagent blank to compensate for any lead present in the cyanide. Also, the relative value of chloroform as the solvent, rather than carbon tetrachloride, should be investigated.

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Table 9. SUMMARY OF DATA ON LEAD
(0.07 mg/l added to water sample)

Method	Number of results	Mean	Median	Minimum	Maximum	50% Range	Standard deviation	95% Confidence limits of the mean
Dithizone[a]	42[b]	0.076	0.070	0.00	0.20	±0.01	0.032	0.076 ± 0.010
Dithizone, unspecified	5	0.102	0.080	0.06	0.20	±0.01	0.057	0.102 ± 0.071
Spectrograph	3	0.093	0.060	0.06	0.16	±0.01	0.058	0.093 ± 0.144
Atomic absorption	2	0.085	0.085	0.08	0.09	±0.01	0.007	------
Polarograph	2[c]	0.105	0.105	0.07	0.14	±0.00	0.050	------
Overall	54[d]	0.081	0.070	0.00	0.20	±0.01	0.036	0.081 ± 0.010

[a] Copies of instructions provided with sample.
[b] Does not include two outliers.
[c] Does not include one outlier.
[d] Does not include three outliers.

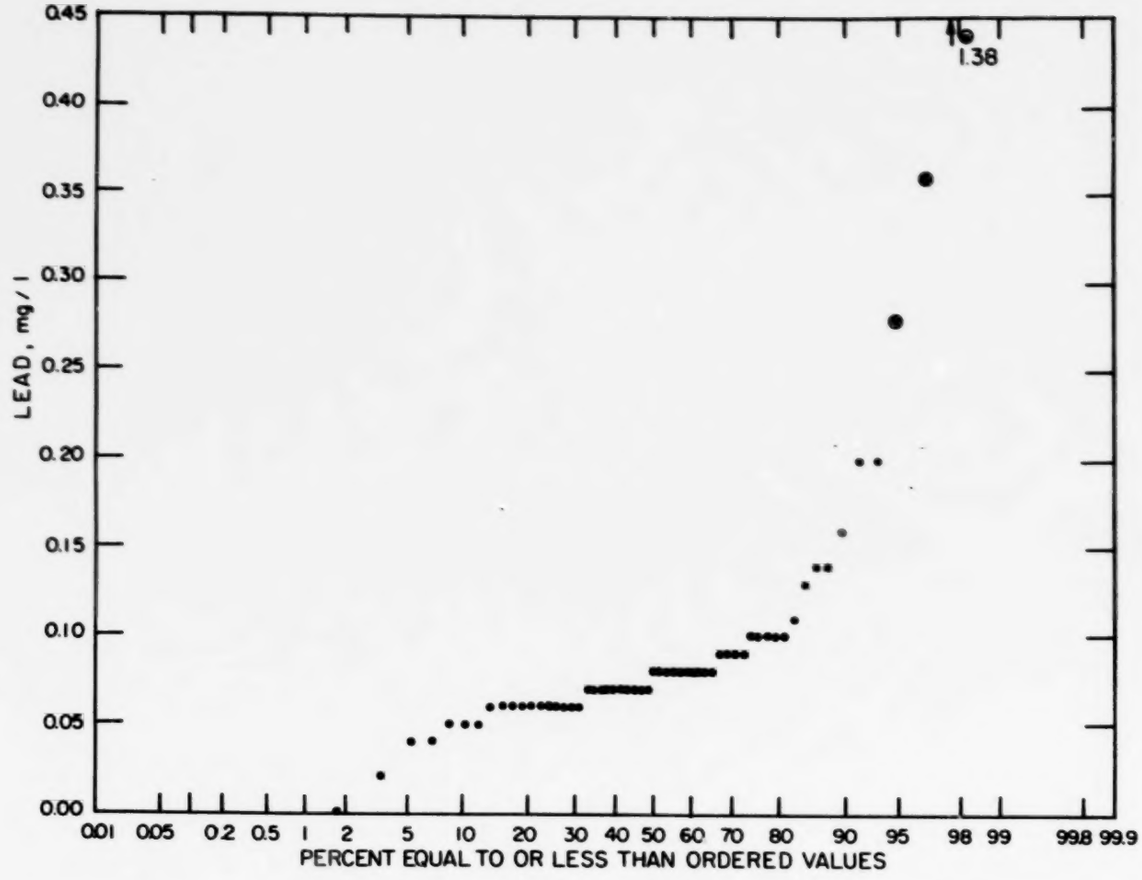

Figure 17. Probability curve for lead.

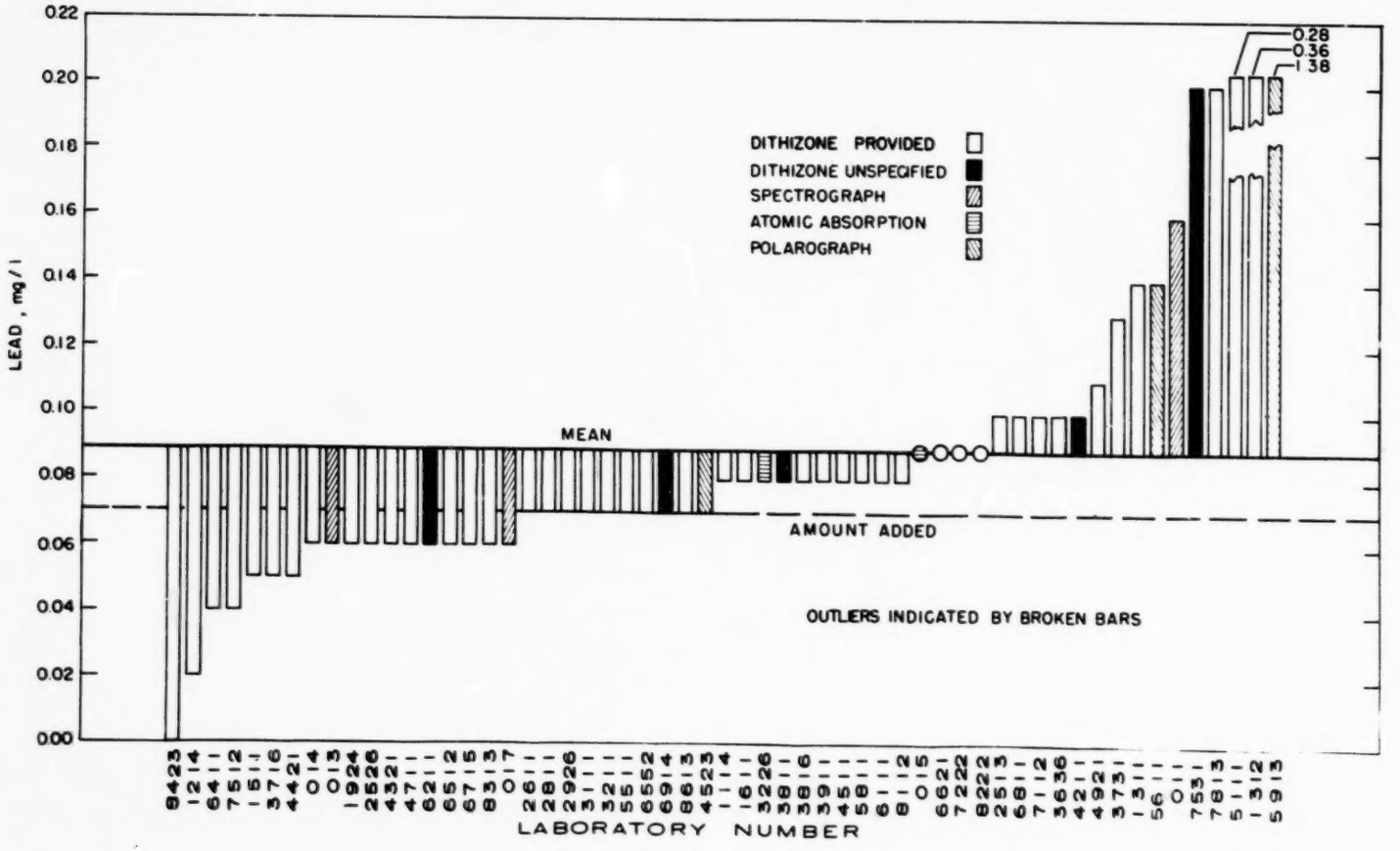

Figure 18. Bar graph for lead.

COMMENTS OF PARTICIPANTS

Although there were general comments such as the sample size was insufficient to permit concentration for the more insensitive procedures and the rubber stopper deteriorated leaving fine particles in the sample, most of the comments received concerned the suggested methods. Several complaints were made that the concentration of metal in the sample was lower than the lowest standard specified in the procedure and that spectrographic analysis for specific minerals added to acidified, distilled, demineralized water is very different from analysis for minerals in average potable water.

In all dithizone procedures, participants believed it would be preferable to use the dithizone solution rather than the blank as a reference. Also, better results could be obtained by use of a shaking machine rather than hand shaking, and the standard dithizone solution should be aged at least for 1 day before use.

More specifically, in regard to the methods used in analyzing for each of the metals, the following comments were received:

1. Silver. For silver, the dithizone method was found to be very sensitive but requires too much glassware and special handling. The value of dessicote was questionable since it may absorb organic material. The method was too unwieldy for routine use and would probably be useful only for research work. Many participants encountered difficulty in trying to evaporate the sample to dryness. They found that after the sulfuric acid is added, if the sample is allowed to cool before it is shaken, vapor pressure is decreased and spattering is prevented. Visual evaluation was believed to be more accurate than spectrophotometric measurement.

2. Lead. In the lead procedure, it was difficult to extract lead dithizonate with the use of carbon tetrachloride. The color produced when the cyanide solution was washed with dithizone was impossible to remove with carbon tetrachloride and extremely difficult with chloroform. The need for extracting the KCN solution was questionable and errors introduced by extra manipulations may have offset any gain from extra separations of interferences. The intense color the dithizone produced in the KCN masked the pH indicator color and made pH adjustment very difficult. It would be preferable to adjust pH before addition of KCN or use a pH meter or Universal pH indicator paper. The carbon tetrachloride used in the new procedure is more toxic to man than the chloroform used in

the present method and was found to be a less efficient solvent. Many participants considered the new procedure to be less reliable than the present standard method. It was suggested that lead standard solutions are more stable if prepared in 1% nitric acid.

3. Zinc. The zincon method for zinc was found to be rapid and simple. Two participants considered the dithizone method for zinc to be unduly lengthy and to require too much special apparatus. It also requires strict adherence to every detail of the procedure and much tedious shaking. On the other hand, two found the dithizone procedure to be very simple and encountered no difficulties.

4. Cadmium. Several participants did encounter difficulty in dissolving cadmium metal to prepare standard solutions. Comment was made that for both cadmium and lead determination with dithizone, the reagents should be fresh. One participant commented that the color of the standards was not stable: the lower standards faded and the high standards increased in color. The curve was linear, however, if the standards were read immediately. Cotton plugs were found to absorb color, so were eliminated. To save time, tartaric acid could be added to the second separatory funnel before dithizone is added to the first funnel. It was also suggested that dithizone should not be added until the analyst is able to carry each extraction through to the tartaric acid. When the tartaric acid was extracted two or three times with chloroform, scum at the interface was found to be less troublesome. The general opinion was that the new procedure was less troublesome than the present method in the 11th edition of Standard Methods.

5. Chromium. In the determination of chromium with diphenylcarbazide, permanganate-azide oxidation was reported by one participant to give low, erratic results when compared with alkaline-hypobromite oxidation.

6. Iron. In the phenanthroline method for iron, the more stable sodium acetate solution was preferred to the ammonium acetate specified in Standard Methods.

7. Aluminum. Many participants considered aluminon methods to be unreliable for the measurement of aluminum, and expressed a desire for a better and more rapid method.

CONCLUSIONS

From the results of the 1,599 analyses, the following conclusions are drawn:

1. Aluminum. Although aluminon was the preferred method for measurement of aluminum, it is not considered a good method and a more reliable one is needed.

2. Copper. Of the many colorimetric reagents used for copper analysis, cuprethol is the most popular, but bathocuproine is more accurate, as is zinc dibenzyl dithiocarbamate.

3. Iron. The majority of analysts used phenanthroline for the determination of iron and achieved better accuracy and precision than those using other reagents.

4. Manganese. The use of persulfate to oxidize manganese to permanganate was chosen by the majority of participants who performed the manganese determination. The use of persulfate as the oxidant produced better accuracy and precision than the use of periodate.

5. Zinc. The dithizone procedure that was provided for the measurement of zinc is the mixed-color procedure in the 11th edition of Standard Methods. The method appears satisfactory, and no difficulties were encountered by most participants. The zincon method was used by only a few participants but produced equally good results.

6. Silver. The measurement of silver was the most difficult determination in the study. The overall tendency was toward low results, but the instrumental techniques produced better accuracy than the dithizone method.

7. Cadmium. The determination of cadmium has long been judged to be one of the more difficult dithizone procedures. The new procedure submitted to the participants apparently was considered much less difficult than the present standard method and produced excellent accuracy and precision.

8. Chromium. Diphenylcarbazide was the only colorimetric reagent used for the determination of chromium. Of the several techniques used to oxidize the chromium from the trivalent form to the hexavalent form, the permanganate-azide procedure was the most widely used and produced generally satisfactory results. Similar accuracy and precision was obtained with the use of the alkaline hypobromite oxidation. The overall tendency was toward slightly low results, probably due to incomplete oxidation of the trivalent chromium.

9. Lead. The dithizone procedure for lead analysis provided with the sample was used by the majority of participants and produced excellent accuracy and precision in spite of the difficulties mentioned by many participants. There is a possibility that with slight modification the method could be further improved.

10. Procedures. Atomic absorption spectroscopy, used for all the metals except aluminum, produced excellent results.

The spectrograph produced good results for zinc and cadmium. The results for aluminum and silver were low; for copper, iron, and manganese, slightly low; and those for chromium and lead, high.

The polarograph showed a tendency toward high results for copper, zinc, chromium, and lead and slightly low results for cadmium. It was not used in analyses for aluminum, iron, manganese, or silver.

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APPENDICES

APPENDIX A.

TABULATION OF RESULTS

Table A-1. TABULATION OF RESULTS FOR ALUMINUM
(0.50 mg/l added to water sample)

Lab. number	Results	Range	Mean	Percent deviation from amount added	Method	Reference
010	0.10 0.10 0.11	0.01	0.10	80	Spectrograph	--
011	0.35 0.29 0.26	0.09	0.30	40	Spectrograph	56
013	0.23 0.28 0.29	0.06	0.27	46	Spectrograph	1
014	0.34 0.34 0.36	0.02	0.35	30	Aluminon	2
017	0.35 0.21 0.26	0.14	0.27	46	Spectrograph	--
018	0.32 0.33 0.33	0.01	0.33	34	Aluminon	11

(Table A-1 continued)

Lab. number	Results	Range	Mean	Percent deviation from amount added	Method	Reference
1114	0.76 0.81 0.78	0.05	0.78	56	8-Hydroxyquinone	15
1211	0.33 0.33 0.33	0.00	0.33	34	Aluminon	2
1214	0.38 0.38 ----	0.00	0.38	24	Haematoxylin	16
1311	0.38 0.36 0.38	0.02	0.37	26	Aluminon	2
1312	0.45 0.42 0.42	0.03	0.43	7	Aluminon	23
1322	0.37 0.40 0.38	0.03	0.38	24	Aluminon	2
1511	0.56 0.55 0.54	0.02	0.55	10	Aluminon	2

(Table A-1 continued)

Lab. number	Results	Range	Mean	Percent deviation from amount added	Method	Reference
1611	0.32 0.32 0.31	0.01	0.32	36	Aluminon	2
1924	0.74 0.64 0.68	0.10	0.68	36	Aluminon	24
2411	0.32 0.31 0.31	0.01	0.31	38	Aluminon	2
2513	0.38 0.40 0.38	0.02	0.39	22	Aluminon	2
2526	0.94 1.10 0.96	0.16	1.00	100	Aluminon	24
2611	0.40 0.34 0.36	0.06	0.37	26	Aluminon	2
2811	0.20 0.21 0.19	0.02	0.20	60	Aluminon	2

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(Table A-1 continued)

Lab. number	Results	Range	Mean	Percent deviation from amount added	Method	Reference
2826	0.52 0.54 0.58	0.06	0.55	10	Aluminon	2
2926	0.38 0.41 0.39	0.03	0.39	22	Aluminon	2
3111	0.36 0.36 0.36	0.00	0.36	28	Aluminon	2
3226	0.41 0.40 0.43	0.03	0.41	18	Aluminon	2
3611	0.38 0.38 0.37	0.01	0.38	24	Aluminon	2
3731	0.48 1.00 0.95	0.52	0.81	62	Aluminon	2
3811	0.31 0.31 0.31	0.00	0.31	38	Aluminon	2

(Table A-1 continued)

Lab. number	Results	Range	Mean	Percent deviation from amount added	Method	Reference
3911	0.80 0.76 0.80	0.04	0.79	58	Aluminon	2
4211	0.41 0.40 0.40	0.01	0.40	20	Aluminon	2
4321	0.00 0.00 ----	0.00	0.00	100	Aluminon	2
4511	0.40 0.41 0.40	0.01	0.40	20	Aluminon	2
4523	0.18 0.18 0.18	0.00	0.18	64	Aluminon	2
4611	0.62 0.62 0.62	0.00	0.62	24	Aluminon	2
4711	0.30 0.34 0.35	0.05	0.33	34	Aluminon	2

(Table A-1 continued)

Lab. number	Results	Range	Mean	Percent deviation from amount added	Method	Reference
4921	0.60 0.57 0.59	0.03	0.59	18	Aluminon	2
5111	0.31 0.31 0.33	0.02	0.32	36	Aluminon	2
5511	0.35 0.35 0.34	0.01	0.35	30	Aluminon	2
5611	0.44 0.44 0.44	0.00	0.44	12	Aluminon	2
5811	0.24 0.24 0.24	0.00	0.24	52	Cyanine R	37
6111	0.36 0.36 0.36	0.00	0.36	28	Aluminon	2
6211	0.37 0.37 0.39	0.02	0.38	24	Aluminon	2

(Table A-1 continued)

Lab. number	Results	Range	Mean	Percent deviation from amount added	Method	Reference
6314	0.51 0.50 0.50	0.01	0.50	0	Aluminon	2
6424	0.28 0.27 0.27	0.01	0.27	46	Aluminon	11
6512	0.36 0.33 0.33	0.03	0.34	32	Aluminon	2
6552	0.38 0.34 0.40	0.06	0.37	26	Aluminon	2
6811	0.52 0.48 0.46	0.06	0.49	2	Aluminon	2
6914	0.33 0.37 0.37	0.04	0.36	28	Alizarin red-S	40
7112	0.19 0.21 0.18	0.03	0.19	62	Fluorometric	42

(Table A-1 continued)

Lab. number	Results	Range	Mean	Percent deviation from amount added	Method	Reference
7222	0.28 0.32 0.30	0.04	0.30	40	Aluminon	2
7512	0.55 0.78 0.78	0.23	0.70	40	Aluminon	2
7622	0.34 0.34 0.34	0.00	0.34	32	Aluminon	2
7722	1.59 1.37 1.48	0.22	1.48	196	Gravimetric	44
8112	0.24 0.30 0.29	0.06	0.28	44	Aluminon	2
8222	0.26 0.27 0.25	0.02	0.26	48	Aluminon	2
8423	0.26 0.27 0.35	0.09	0.29	42	Ferron ortho-phenanthroline	48

(Table A-1 continued)

Lab. number	Results	Range	Mean	Percent deviation from amount added	Method	Reference
8512	0.40 0.36 ----	0.04	0.38	24	Aluminon	2
8613	0.30 0.33 0.31	0.03	0.31	38	Eriochrome cyanine R. C.	49

Table A-2. TABULATION OF RESULTS FOR COPPER
(0.47 mg/l added to water sample)

Lab. number	Results	Range	Mean	Percent deviation from amount added	Method	Reference
010	0.41 0.48 0.48	0.07	0.46	2	Spectrograph	--
011	0.47 0.31 0.28	0.19	0.35	26	Spectrograph	56
014	0.46 0.47 0.47	0.01	0.47	0	Bathocuproine	2
015	0.47 0.47 0.47	0.00	0.47	0	Atomic absorption	3
017	0.36 0.41 0.40	0.05	0.39	17	Spectrograph	--
018	0.28 0.30 0.30	0.02	0.29	38	Bis (cyclanon)-oxal-dihydrazon	12
018	0.47 0.46 0.46	0.01	0.46	2	Zinc-dibenzyl dithiocarbamate	13

(Table A-2 continued)

Lab. number	Results	Range	Mean	Percent deviation from amount added	Method	Reference
1114	0.44 0.48 0.46	0.04	0.46	2	Zinc-dibenzyl dithiocarbamate	--
1214	0.53 0.51 ----	0.02	0.52	11	Sodium diethyl dithiocarbamate	17
1311	0.52 0.50 0.51	0.02	0.51	8	Cuprethol	2
1312	0.72 0.72 0.72	0.00	0.72	53	Cuprethol	23
1322	0.50 0.50 0.50	0.00	0.50	6	Cuprethol	2
1511	0.50 0.60 0.60	0.10	0.57	21	Cuprethol	2
1611	0.40 0.41 0.41	0.01	0.41	13	Neocuproine	2

(Table A-2 continued)

Lab. number	Results	Range	Mean	Percent deviation from amount added	Method	Reference
1924	0.52 0.47 0.50	0.05	0.50	6	Sodium diethyl dithiocarbamate	2
2144	0.48 0.46 0.49	0.03	0.48	2	--------	26
2411	0.47 0.50 0.48	0.03	0.48	2	Cuprethol	2
2411	0.46 0.47 0.48	0.02	0.47	0	Bathocuproine	2
2513	0.49 0.51 0.51	0.02	0.50	6	Cuprethol	2
2526	0.65 0.66 0.71	0.06	0.67	42	Cuprethol	4
2611	0.38 0.40 0.43	0.05	0.40	15	Sodium diethyl dithiocarbamate	24

(Table A-2 continued)

Lab. number	Results	Range	Mean	Percent deviation from amount added	Method	Reference
2811	0.62 0.62 0.64	0.02	0.63	34	Sodium diethyl dithiocarbamate	28
2826	0.48 0.46 0.49	0.03	0.48	2	Sodium diethyl dithiocarbamate	30
2926	0.49 0.50 0.50	0.01	0.50	6	Sodium diethyl dithiocarbamate	24
3111	0.46 0.46 0.46	0.00	0.46	2	Bathocuproine	2
3211	0.52 0.50 0.53	0.03	0.52	11	Cuprethol	2
3226	0.48 0.49 0.49	0.01	0.49	4	Atomic absorption	50
3611	0.50 0.51 0.50	0.01	0.50	6	Polarograph	33

(Table A-2 continued)

Lab. number	Results	Range	Mean	Percent deviation from amount added	Method	Reference
3611	0.50 0.50 0.51	0.01	0.50	6	Neocuproine	--
3636	0.44 0.44 0.44	0.00	0.44	6	Bathocuproine	2
3716	0.70 0.71 0.70	0.01	0.70	49	Polarograph	58
3731	0.39 0.35 0.38	0.04	0.37	21	--------	--
3811	0.50 0.50 0.50	0.00	0.50	6	Cuprethol	2
3911	0.25 0.26 0.26	0.01	0.26	45	Cuprethol	2
4211	0.38 0.35 0.35	0.03	0.36	23	Cuprethol	2

(Table A-2 continued)

Lab. number	Results	Range	Mean	Percent deviation from amount added	Method	Reference
4321	0.41 0.42 0.41	0.01	0.41	13	Sodium diethyl dithiocarbamate	36
4421	0.45 0.44 0.44	0.01	0.44	6	Zinc-dibenzyl dithiocarbamate	34
4511	0.47 0.48 0.47	0.01	0.47	0	Cuprethol	35
4511	---- 0.47 ----	----	0.47	0	Atomic absorption	--
4523	0.47 0.48 0.45	0.03	0.47	0	Polarograph	--
4611	0.45 0.46 0.47	0.02	0.46	2	Neocuproine	2
4711	0.50 0.46 0.50	0.04	0.49	4	Cuprethol	2

(Table A-2 continued)

Lab. number	Results	Range	Mean	Percent deviation from amount added	Method	Reference
4921	0.48 0.49 0.51	0.03	0.49	4	Cuprethol	2
5111	0.54 0.48 0.51	0.06	0.51	8	Sodium diethyl dithiocarbamate	36
5511	0.46 0.47 0.47	0.01	0.47	0	Bathocuproine	2
5611	---- 0.86 ----	----	0.86	83	Polarograph	--
5811	0.52 0.52 0.52	0.00	0.52	11	Sodium diethyl dithiocarbamate	25
5913	0.47 0.48 0.47	0.01	0.47	0	Sodium diethyl dithiocarbamate	24
6111	0.52 0.52 0.50	0.02	0.51	8	Bathocuproine	2

(Table A-2 continued)

Lab. number	Results	Range	Mean	Percent deviation from amount added	Method	Reference
6211	0.52 0.51 0.52	0.01	0.52	11	Cuprethol	2
6314	0.48 0.47 0.47	0.01	0.47	0	Cuprethol	2
6512	0.47 0.47 0.47	0.00	0.47	0	Cuprethol	2
6552	0.58 0.58 0.56	0.02	0.57	21	Cuprethol	2
6715	0.47 0.57 0.47	0.00	0.47	0	Bathocuproine	59
6811	0.50 0.54 0.48	0.06	0.51	8	Cuprethol	2
6914	0.48 0.48 0.48	0.00	0.48	2	Zinc-dibenzyl dithiocarbamate	34

(Table A-2 continued)

Lab. number	Results	Range	Mean	Percent deviation from amount added	Method	Reference
7112	0.46 0.44 0.45	0.02	0.45	4	Cuprethol	2
7222	0.31 0.32 0.31	0.01	0.31	34	Neocuproine	2
7512	0.40 0.50 0.45	0.10	0.45	4	Cuprethol	2
7522	0.48 0.52 0.50	0.04	0.50	6	Cuprethol	2
7622	0.48 0.49 0.48	0.01	0.48	2	Neocuproine	2
7813	0.36 0.36 0.36	0.00	0.36	23	Cuprethol	45
8112	0.52 0.56 0.52	0.04	0.53	13	Neocuproine	2

(Table A-2 continued)

Lab. number	Results	Range	Mean	Percent deviation from amount added	Method	Reference
8222	0.46 0.46 0.46	0.00	0.46	2	Cuprethol	2
8423	0.50 0.51 0.48	0.03	0.50	6	Sodium diethyl dithiocarbamate	48
8512	0.55 0.56 0.50 0.50	0.06	0.53	13	Cuprethol	2
8613	0.50 0.50 0.50	0.00	0.50	6	Sodium diethyl dithiocarbamate	48

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Table A-3. TABULATION OF RESULTS FOR IRON
(0.30 mg/l added to water sample)

Lab. number	Results	Range	Mean	Percent deviation from amount added	Method	Reference
010	0.36 0.32 0.29	0.07	0.32	7	Spectrograph	--
011	0.39 0.40 0.20	0.20	0.33	10	Spectrograph	56
013	0.15 0.11 0.09	0.06	0.12	60	Spectrograph	1
014	0.34 0.33 0.32	0.02	0.33	10	Phenanthroline	2
015	0.35 0.35 0.35	0.00	0.35	17	Atomic absorption	4
017	0.33 0.27 0.30	0.06	0.30	0	Spectrograph	--
018	0.34 0.35 0.35	0.01	0.35	17	Thiocyanate	14

(Table A-3 continued)

Lab. number	Results	Range	Mean	Percent deviation from amount added	Method	Reference
018	0.40 0.42 0.41	0.02	0.41	37	2, 4, 6-Tripyridyl-s-triazine	9
1114	0.36 0.36 0.38	0.02	0.37	23	Thiocyanate	--
1114	0.33 0.30 0.32	0.03	0.32	7	4,7-Diphenyl-1,10-phenanthroline	15
1211	0.30 0.30 0.30	0.00	0.30	0	Phenanthroline	2
1214	0.25 0.26 0.25	0.01	0.25	17	Thioglycolic acid	18
1311	0.50 0.50 0.50	0.00	0.50	67	Phenanthroline	2
1312	0.44 0.44 0.44	0.00	0.44	47	Phenanthroline	23

(Table A-3 continued)

Lab. number	Results	Range	Mean	Percent deviation from amount added	Method	Reference
1322	0.32 0.32 0.32	0.00	0.32	7	Phenanthroline	2
1511	0.50 0.52 0.55	0.05	0.52	73	Phenanthroline	2
1611	0.45 0.45 0.41	0.04	0.44	47	Thiocyanate	2
1924	0.32 0.32 0.33	0.01	0.32	7	Phenanthroline	2
2411	0.32 0.32 0.31	0.01	0.32	7	Phenanthroline	2
2513	0.38 0.40 0.38	0.02	0.39	30	Phenanthroline	2
2526	0.40 0.39 0.40	0.01	0.40	33	Thiocyanate	--

(Table A-3 continued)

Lab. number	Results	Range	Mean	Percent deviation from amount added	Method	Reference
2611	0.45 0.36 0.36	0.09	0.39	30	Tripyridine	2
2714	0.34 0.34 0.36	0.02	0.34	13	Phenanthroline	2
2811	0.30 0.31 0.29	0.02	0.30	0	Phenanthroline	2
2826	0.80 0.80 0.83	0.03	0.81	170	Thioglycolic acid	--
2915	0.26 0.26 0.28	0.02	0.27	10	Tripyridine	2
2926	0.30 0.31 0.31	0.01	0.31	3	Phenanthroline	2
3111	0.25 0.27 0.28	0.03	0.27	10	Thiocyanate	25

(Table A-3 continued)

Lab. number	Results	Range	Mean	Percent deviation from amount added	Method	Reference
3211	0.30 0.30 0.30	0.00	0.30	0	Phenanthroline	2
3226	0.33 0.33 0.33	0.00	0.33	10	Atomic absorption	50
3611	0.07 0.08 0.08	0.01	0.08	73	Phenanthroline	2
3636	0.32 0.32 0.34	0.02	0.33	10	2,2'-Bipyridine	30
3716	0.52 0.51 0.48	0.04	0.50	67	Phenanthroline	2
3731	0.34 0.34 0.34	0.00	0.34	13	Phenanthroline	2
3811	0.30 0.34 0.30	0.04	0.31	3	Phenanthroline	2

(Table A-3 continued)

Lab. number	Results	Range	Mean	Percent deviation from amount added	Method	Reference
3911	0.40 0.36 0.40	0.04	0.39	33	Phenanthroline	2
4211	0.29 0.30 0.31	0.02	0.30	0	Phenanthroline	2
4321	0.30 0.30 ----	0.00	0.30	0	Thiocyanate	36
4421	0.22 0.24 ----	0.02	0.23	23	Phenanthroline	2
4511	0.32 0.32 0.32	0.00	0.32	7	Phenanthroline	2
4511	---- 0.24 ----	----	0.24	20	Atomic absorption	2
4523	0.43 0.42 0.42	0.01	0.42	40	Phenanthroline	2

(Table A-3 continued)

Lab. number	Results	Range	Mean	Percent deviation from amount added	Method	Reference
4611	0.36 0.35 0.37	0.02	0.36	20	Phenanthroline	2
4711	0.44 0.44 0.46	0.02	0.45	50	Tripyridine	2
4921	0.38 0.35 0.30	0.08	0.34	13	Phenanthroline	2
5111	0.20 0.25 0.20	0.05	0.22	27	Thiocyanate	25
5511	0.29 0.29 0.29	0.00	0.29	3	Phenanthroline	2
5611	0.30 0.25 0.25	0.05	0.27	10	Phenanthroline	2
5811	0.35 0.35 0.35	0.00	0.35	17	Thiocyanate	25

(Table A-3 continued)

Lab. number	Results	Range	Mean	Percent deviation from amount added	Method	Reference
6111	0.32 0.31 0.31	0.01	0.31	3	Tripyridine	2
6211	0.29 0.30 0.30	0.01	0.30	0	Phenanthroline	24
6314	0.32 0.33 0.32	0.01	0.32	7	Phenanthroline	2
6411	0.28 0.30 0.28	0.02	0.29	3	Phenanthroline	2
6424	0.31 0.30 0.30	0.01	0.30	0	Phenanthroline	2
6512	0.30 0.30 0.29	0.01	0.30	0	Phenanthroline	2
6536	0.34 0.35 0.35	0.01	0.35	17	Thiocyanate	36

(Table A-3 continued)

Lab. number	Results	Range	Mean	Percent deviation from amount added	Method	Reference
6552	0.48 0.54 0.46	0.08	0.49	63	Phenanthroline	2
6621	0.82 0.80 0.82	0.02	0.81	170	Tripyridine	2
6715	0.03 0.03 0.03	0.00	0.03	90	Tripyridine	2
6811	0.32 0.34 0.33	0.02	0.33	10	Bathophenanthroline	38
6914	0.32 0.32 0.30	0.02	0.31	3	Phenanthroline	2
7112	0.32 0.30 0.30	0.02	0.31	3	Phenanthroline	2
7222	0.31 0.31 0.30	0.01	0.31	3	Phenanthroline	2

(Table A-3 continued)

Lab. number	Results	Range	Mean	Percent deviation from amount added	Method	Reference
7512	0.30 0.32 0.29	0.03	0.30	0	Phenanthroline	2
7522	0.30 0.32 0.30	0.02	0.31	3	Phenanthroline	2
7526	0.12 0.12 0.10	0.02	0.11	63	Tripyridine	2
7622	0.52 0.54 0.53	0.02	0.53	77	Phenanthroline	2
7722	0.39 0.40 0.81	0.42	0.53	77	Thiocyanate	44
7813	0.30 0.34 0.32	0.04	0.32	7	α,α'-Dipyridyl	46
8112	0.34 0.33 0.34	0.01	0.34	13	Phenanthroline	2

(Table A-3 continued)

Lab. number	Results	Range	Mean	Percent deviation from amount added	Method	Reference
8222	0.22 0.24 0.22	0.02	0.23	23	Phenanthroline	2
8313	0.29 0.29 0.28	0.01	0.29	3	Thiocyanate	36
8423	0.33 0.33 0.32	0.01	0.33	10	Bipyridine	48
8512	0.30 0.31 0.32	0.02	0.31	3	Phenanthroline	2
8613	0.32 0.32 0.32	0.00	0.32	7	Bipyridine	48

Table A-4. TABULATION OF RESULTS FOR MANGANESE
(0.12 mg/l added to water sample)

Lab. number	Results	Range	Mean	Percent deviation from amount added	Method	Reference
010	0.11 0.07 0.10	0.04	0.09	25	Spectrograph	--
011	0.15 0.14 0.08	0.07	0.12	0	Spectrograph	56
013	0.09 0.11 0.09	0.02	0.10	17	Spectrograph	1
014	0.12 0.12 0.12	0.00	0.12	0	Persulfate	2
015	0.10 0.10 0.10	0.00	0.10	17	Atomic absorption	5
017	0.15 0.12 0.14	0.03	0.14	17	Spectrograph	--
018	0.15 0.15 0.15	0.00	0.15	25	Persulfate	2

(Table A-4 continued)

Lab. number	Results	Range	Mean	Percent deviation from amount added	Method	Reference
018	0.14 0.14 0.14	0.00	0.14	17	Formaldoxime	10
018	0.14 0.14 0.15	0.01	0.14	17	Formaldoxime (Automatic analyzer)	10
1114	0.29 0.23 0.26	0.06	0.26	117	Formaldoxime	15
1114	0.21 0.21 ----	0.00	0.21	75	Periodate	15
1211	0.10 0.10 0.10	0.00	0.10	17	Persulfate	2
1214	0.34 0.30 ----	0.04	0.32	167	Persulfate	19
1311	0.13 0.13 0.13	0.00	0.13	8	Periodate	2

(Table A-4 continued)

Lab. number	Results	Range	Mean	Percent deviation from amount added	Method	Reference
1312	0.06 0.06 0.06	0.00	0.06	50	Persulfate	23
1322	0.12 0.12 0.12	0.00	0.12	0	Periodate	2
1511	0.50 0.50 0.53	0.03	0.51	325	Persulfate	2
1924	0.11 0.10 0.11	0.01	0.11	8	Persulfate	24
2411	0.16 0.16 0.16	0.00	0.16	33	Periodate	2
2526	0.38 0.32 0.38	0.06	0.36	200	Persulfate	24
2611	0.12 0.12 0.12	0.00	0.12	0	Persulfate	2

(Table A-4 continued)

Lab. number	Results	Range	Mean	Percent deviation from amount added	Method	Reference
2811	0.12 0.12 0.13	0.01	0.12	0	Persulfate	2
2826	0.40 0.20 0.20	0.20	0.26	117	Periodate	2
2926	0.11 0.10 0.10	0.01	0.10	17	Persulfate	2
3111	0.18 0.15 0.15	0.03	0.16	33	Periodate	2
3211	0.15 0.13 0.14	0.02	0.14	17	Persulfate	2
3226	0.15 0.15 0.15	0.00	0.15	25	Atomic absorption	50
3611	0.11 0.12 0.12	0.01	0.12	0	Persulfate	2

(Table A-4 continued)

Lab. number	Results	Range	Mean	Percent deviation from amount added	Method	Reference
3636	0.15 0.15 0.15	0.00	0.15	25	Persulfate	2
3731	0.15 0.15 0.15	0.00	0.15	25	Periodate	2
3811	0.10 0.10 0.10	0.00	0.10	17	Periodate	2
3911	0.06 0.08 0.05	0.03	0.06	50	Persulfate	2
4211	0.10 0.10 0.10	0.00	0.10	17	Persulfate	2
4321	0.05 0.05 ----	0.00	0.05	58	Tetrabase (tetramethyl-p-diamino diphenyl methane)	60
4421	0.14 0.14 0.14	0.00	0.14	17	Persulfate	2

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(Table A-4 continued)

Lab. number	Results	Range	Mean	Percent deviation from amount added	Method	Referenc
4523	0.03 0.03 0.03	0.00	0.03	75	Persulfate	2
4611	0.13 0.17 0.18	0.05	0.16	33	Periodate	2
4711	0.12 0.11 0.11	0.01	0.11	8	Periodate	2
4921	0.11 0.10 0.09	0.02	0.10	17	Persulfate	2
5111	0.13 0.13 0.13	0.00	0.13	8	Persulfate	2
5511	0.11 0.12 0.11	0.01	0.11	8	Persulfate	2
5611	0.10 0.10 0.10	0.00	0.10	17	Persulfate	2

(Table A-4 continued)

Lab. number	Results	Range	Mean	Percent deviation from amount added	Method	Reference
5811	0.12 0.12 0.12	0.00	0.12	0	Persulfate	2
5913	0.15 0.15 0.15	0.00	0.15	25	Persulfate	2
6211	0.13 0.11 0.11	0.02	0.12	0	Persulfate	2
6314	0.11 0.12 0.11	0.01	0.11	8	Persulfate	2
6424	0.12 0.12 0.12	0.00	0.12	0	Persulfate	2
6536	0.10 0.11 0.11	0.01	0.11	8	Persulfate	24
6552	0.12 0.13 0.11	0.02	0.12	0	Persulfate	2

(Table A-4 continued)

Lab. number	Results	Range	Mean	Percent deviation from amount added	Method	Reference
6811	0.14 0.11 0.12	0.03	0.12	0	Periodate	2
6914	0.20 0.20 0.20	0.00	0.20	67	Periodate	2
7112	0.22 0.20 0.20	0.02	0.21	67	Persulfate	2
7222	0.12 0.11 0.11	0.01	0.11	8	Persulfate	2
7512	0.13 0.13 0.13	0.00	0.13	8	Persulfate	2
7522	0.11 0.12 0.14	0.03	0.12	0	Persulfate	2
7622	0.13 0.12 0.12	0.01	0.12	0	Persulfate	2

(Table A-4 continued)

Lab. number	Results	Range	Mean	Percent deviation from amount added	Method	Reference
7813	0.04 0.03 0.04	0.01	0.04	67	Periodate	47
8112	0.18 0.18 0.18	0.00	0.18	50	Periodate	2
8222	0.14 0.14 0.14	0.00	0.14	17	Persulfate	2
8423	0.00 0.00 0.00	0.00	0.00	100	Unspecified	48
8512	0.14 0.14 ----	0.00	0.14	17	Persulfate	2
8613	0.13 0.13 0.13	0.00	0.13	8	Atomic absorption	50

Table A-5. TABULATION OF RESULTS FOR ZINC
(0.65 mg/l added to water sample)

Lab. number	Results	Range	Mean	Percent deviation from amount added	Method	Reference
011	0.63 0.68 0.71	0.08	0.67	3	Spectrograph	56
013	0.91 1.02 0.95	0.11	0.96	48	Spectrograph	1
014	0.81 0.78 0.79	0.03	0.79	22	Dithizone	51
015	0.78 0.77 0.78	0.01	0.78	20	Atomic absorption	6
017	0.78 0.85 0.82	0.08	0.82	26	Spectrograph	--
018	0.96 0.94 0.95	0.02	0.95	46	Dithizone	51
1114	0.89 0.85 0.87	0.04	0.87	34	Dithizone	51

(Table A-5 continued)

Lab. number	Results	Range	Mean	Percent deviation from amount added	Method	Reference
1114	0.96 0.92 0.89	0.07	0.92	42	Polarograph	53
1214	0.84 0.89 ----	0.05	0.86	32	Dithizone	51
1311	1.00 1.00 1.00	0.00	1.00	54	Dithizone	51
1511	1.29 1.30 1.32	0.03	1.30	100	Dithizone	51
1611	0.85 0.85 0.88	0.03	0.86	32	Dithizone	51
1924	0.77 0.78 0.77	0.01	0.77	18	Dithizone	51
2144	0.63 0.63 0.64	0.01	0.63	3	Zincon	52

(Table A-5 continued)

Lab. number	Results	Range	Mean	Percent deviation from amount added	Method	Reference
2513	0.72 0.76 0.79	0.07	0.76	17	Dithizone	51
2526	0.68 0.70 0.68	0.02	0.69	6	Dithizone	51
2611	0.88 0.86 0.90	0.04	0.88	35	Dithizone	51
2714	0.94 0.94 0.93	0.01	0.94	45	Polarograph	27
2811	0.77 0.73 0.76	0.04	0.75	15	Dithizone	51
2826	0.95 1.02 1.02	0.07	1.00	54	Zincon	31
2915	0.62 0.63 0.63	0.01	0.63	3	Dithizone	51

(Table A-5 continued)

Lab. number	Results	Range	Mean	Percent deviation from amount added	Method	Reference
2926	0.67 0.70 0.72	0.05	0.70	8	Dithizone	51
2926	0.74 0.73 0.73	0.01	0.73	12	Zincon	52
3111	0.72 0.72 0.72	0.00	0.72	11	Dithizone	2
3211	0.78 0.74 0.84	0.10	0.79	22	Dithizone	51
3226	0.80 0.80 0.80	0.00	0.80	23	Atomic absorption	50
3226	0.80 0.78 0.80	0.02	0.79	22	Zincon	52
3514	1.00 1.00 1.02	0.02	1.01	55	Dithizone	51

(Table A-5 continued)

Lab. number	Results	Range	Mean	Percent deviation from amount added	Method	Reference
3611	0.73 0.72 0.73	0.01	0.73	12	Polarograph	53
3611	0.77 0.76 0.78	0.02	0.77	18	Dithizone	51
3716	0.90 0.90 0.84	0.06	0.88	35	Dithizone	51
3716	0.98 1.02 0.98	0.04	0.99	52	Polarograph	53
3731	0.60 0.40 0.48	0.20	0.49	25	Dithizone	51
3811	0.80 0.80 0.80	0.00	0.80	23	Dithizone	51
3911	0.80 0.70 0.85	0.15	0.78	20	Dithizone	51

(Table A-5 continued)

Lab. number	Results	Range	Mean	Percent deviation from amount added	Method	Reference
4211	0.78 0.78 0.73	0.05	0.76	17	Dithizone	2
4321	0.80 0.76 ----	0.04	0.78	20	Dithizone	51
4421	0.70 0.78 0.83	0.13	0.77	18	Dithizone	51
4511	0.77 0.76 0.75	0.02	0.76	17	Dithizone	2
4511	0.75 ---- ----	----	0.75	15	Atomic absorption	--
4523	0.87 0.88 0.89	0.02	0.88	35	Polarograph	--
4611	0.83 0.83 0.86	0.03	0.84	29	Dithizone	51

(Table A-5 continued)

Lab. number	Results	Range	Mean	Percent deviation from amount added	Method	Reference
4711	0.65 0.66 0.66	0.01	0.66	2	Dithizone	51
4921	0.92 0.90 0.89	0.03	0.90	38	Dithizone	51
5111	0.75 0.70 0.73	0.05	0.73	12	Dithizone	51
5511	0.80 0.80 0.82	0.02	0.81	25	Dithizone	51
5611	0.86 ---- ----	----	0.86	32	Polarograph	--
5811	0.86 0.85 0.83	0.03	0.85	31	Dithizone	51
5913	1.10 1.10 1.10	0.00	1.10	69	Polarograph	53

(Table A-5 continued)

Lab. number	Results	Range	Mean	Percent deviation from amount added	Method	Reference
6211	0.70 0.72 0.72	0.02	0.72	11	Dithizone	51
6314	0.85 0.89 1.00	0.15	0.91	40	Dithizone	51
6411	0.87 0.87 0.87	0.00	0.87	34	Zincon	52
6411	0.85 0.87 0.88	0.03	0.87	34	Dithizone	51
6512	0.94 0.94 0.93	0.01	0.94	45	Dithizone	51
6552	0.83 0.87 0.88	0.05	0.86	32	Dithizone	51
6621	0.59 0.60 0.61	0.02	0.60	77	Dithizone	2

(Table A-5 continued)

Lab. number	Results	Range	Mean	Percent deviation from amount added	Method	Reference
6715	0.76 0.76 0.75	0.01	0.76	17	Dithizone	51
6811	0.78 0.82 0.80	0.04	0.80	22	Dithizone	51
6811	0.91 ---- ----	----	0.91	40	Polarograph	53
6914	0.74 0.68 0.74	0.06	0.72	11	Dithizone	51
7112	0.75 0.75 0.72	0.03	0.74	14	Dithizone	51
7222	0.80 0.76 0.77	0.04	0.78	20	Dithizone	51
7512	0.80 0.60 1.00	0.40	0.80	23	Dithizone	51

(Table A-5 continued)

Lab. number	Results	Range	Mean	Percent deviation from amount added	Method	Reference
7526	1.03 1.04 1.08	0.05	1.05	62	Dithizone	15
7622	0.78 0.77 0.74	0.04	0.76	17	Dithizone	51
7813	0.99 1.15 1.01	0.16	1.01	55	Dithizone	51
8112	0.88 0.90 0.92	0.04	0.90	38	Dithizone	51
8222	0.34 0.36 0.32	0.04	0.34	48	Dithizone	51
8423	1.10 1.10 1.05	0.05	1.08	66	Dithizone	51
8512	0.82 1.00 0.96 0.92	0.18	0.96	48	Dithizone	51
8613	0.82 0.84 0.80	0.04	0.82	26	Zincon	52

Table A-6. TABULATION OF RESULTS FOR SILVER
(0.15 mg/l added to water sample)

Lab. number	Results	Range	Mean	Percent deviation from amount added	Method	Reference
010	0.11 0.10 0.10	0.01	0.10	33	Spectrograph	--
011	0.09 0.12 0.12	0.03	0.11	27	Spectrograph	56
013	0.02 0.02 0.02	0.00	0.02	87	Spectrograph	1
014	0.09 0.10 0.10	0.01	0.10	33	Dithizone	57
015	0.22 0.24 0.27	0.05	0.24	60	Atomic absorption	7
017	0.15 0.13 0.17	0.04	0.15	0	Spectrograph	--
1114	0.05 0.05 ----	0.00	0.05	67	Dithizone	57

(Table A-6 continued)

Lab. number	Results	Range	Mean	Percent deviation from amount added	Method	Reference
1211	0.06 0.07 0.06	0.01	0.06	60	Dithizone	57
2526	0.02 0.02 0.02	0.00	0.02	87	Dithizone	57
2611	0.25 0.25 0.25	0.00	0.25	67	Dithizone	15
2811	0.14 0.14 0.16	0.02	0.15	0	Dithizone	29
2926	0.02 0.02 0.02	0.00	0.02	87	Dithizone	57
3111	0.06 0.06 ----	0.00	0.06	60	Dithizone	57
3731	0.14 0.03 0.12	0.09	0.10	33	Dithizone	57

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(Table A-6 continued)

Lab. number	Results	Range	Mean	Percent deviation from amount added		Reference
3811	0.07 0.07 0.07	0.00	0.07	53	Dithizone	57
3911	0.00 0.00 0.01	0.01	0.00	100	Dithizone	57
4321	0.25 0.25 ----	0.00	0.25	67	Dithizone	57
4511	0.11 ---- ----	----	0.11	27	Atomic absorption	--
4711	0.02 0.02 0.02	0.00	0.02	87	Dithizone	57
6811	0.05 0.05 0.06	0.01	0.05	67	Dithizone	57
7112	0.05 0.06 0.05	0.01	0.05	67	Dithizone	57

(Table A-6 continued)

Lab. number	Results	Range	Mean	Percent deviation from amount added	Method	Reference
7222	0.05 0.06 ----	0.01	0.06	60	Dithizone	57
8222	0.02 0.01 0.04	0.03	0.02	87	Dithizone	57

Table A-7. TABULATION OF RESULTS FOR CADMIUM
(0.05 mg/l added to water sample)

Lab. number	Results	Range	Mean	Percent deviation from amount added	Method	Reference
011	0.04 0.05 0.05	0.01	0.05	0	Spectrograph	56
013	0.07 0.06 0.06	0.01	0.06	20	Spectrograph	1
014	0.05 0.05 0.05	0.00	0.05	0	Dithizone	54
014	0.05 0.05 0.05	0.00	0.05	0	Atomic absorption	
017	<0.05 <0.05 ----	---- (not used)	<0.05	--	Spectrograph	--
1114	0.08 0.09 0.09	0.01	0.09	80	Dithizone	54
1214	0.23 0.25 ----	0.02	0.24	380	Polarograph	20

(Table A-7 continued)

Lab. number	Results	Range	Mean	Percent deviation from amount added	Method	Reference
1311	0.05 0.05 0.05	0.00	0.05	0	Dithizone	22
1312	0.04 0.04 0.04	0.00	0.04	20	Dithizone	54
1511	0.15 0.13 0.20	0.07	0.16	220	Dithizone	54
1611	0.05 0.05 0.05	0.00	0.05	0	Dithizone	54
1924	0.06 0.05 0.06	0.01	0.06	20	Dithizone	54
2513	0.05 0.05 0.05	0.00	0.05	0	Dithizone	54
2526	0.05 0.06 0.06	0.01	0.06	20	Dithizone	54

(Table A-7 continued)

Lab. number	Results	Range	Mean	Percent deviation from amount added	Method	Reference
2611	0.06 0.06 0.05	0.01	0.06	20	Dithizone	54
2811	0.05 0.05 0.05	0.00	0.05	0	Dithizone	54
2926	0.05 0.05 0.05	0.00	0.05	0	Dithizone	54
3111	0.06 0.06 0.06	0.00	0.06	20	Dithizone	54
3211	0.06 0.06 0.06	0.00	0.06	20	Dithizone	54
3611	0.05 0.05 0.05	0.00	0.05	0	Polarograph	33
3611	0.06 0.06 0.06	0.00	0.06	20	Dithizone	54

(Table A-7 continued)

Lab. number	Results	Range	Mean	Percent deviation from amount added	Method	Reference
3636	0.06 0.06 0.06	0.00	0.06	20	Dithizone	54
3716	0.04 0.05 0.05	0.01	0.05	0	Dithizone	54
3731	0.04 0.04 0.06	0.02	0.05	0	Dithizone	54
3811	0.05 0.05 0.05	0.00	0.05	0	Dithizone	54
3816	0.03 0.05 0.05	0.02	0.04	20	Dithizone	54
3911	0.90 0.92 0.86	0.06	0.89	1680	Dithizone	54
4321	0.05 0.04 ----	0.01	0.04	20	Dithizone	54

(Table A-7 continued)

Lab. number	Results	Range	Mean	Percent deviation from amount added	Method	Reference
4421	0.06 0.06 0.06	0.00	0.06	20	Dithizone	54
4511	0.05 0.05 0.05	0.00	0.05	0	Dithizone	54
4511	0.05 ---- ----	----	0.05	0	Atomic absorption	--
4523	0.03 0.03 0.03	0.00	0.03	40	Polarograph	--
4611	0.05 0.05 0.05	0.00	0.05	0	Dithizone	54
4711	0.04 0.05 0.05	0.01	0.05	0	Dithizone	54
4921	0.02 0.02 0.02	0.00	0.02	60	Dithizone	54

(Table A-7 continued)

Lab. number	Results	Range	Mean	Percent deviation from amount added	Method	Reference
5111	0.05 0.05 0.05	0.00	0.05	0	Dithizone	54
5511	0.05 0.06 0.05	0.01	0.05	0	Dithizone	54
5611	0.09 0.07 ----	0.02	0.08	60	Polarograph	--
5811	0.05 0.05 0.05	0.00	0.05	0	Dithizone	54
5913	0.00 0.00 0.00	0.00	0.00	100	Polarograph	33
6211	0.05 0.05 0.05	0.00	0.05	0	Dithizone	54
6226	0.05 0.05 0.05	0.00	0.05	0	Dithizone	54

(Table A-7 continued)

Lab. number	Results	Range	Mean	Percent deviation from amount added	Method	Reference
6411	0.06 0.06 0.05	0.01	0.06	20	Dithizone	54
6512	0.05 0.05 0.05	0.00	0.05	0	Dithizone	54
6552	0.05 0.05 0.05	0.00	0.05	0	Dithizone	54
6621	0.05 0.05 0.06	0.01	0.05	0	Dithizone	54
6715	0.05 0.05 0.05	0.00	0.05	0	Dithizone	54
6811	0.04 0.04 0.05	0.01	0.04	20	Dithizone	54
6811	0.05 ---- ----	----	0.05	0	Polarograph	--

(Table A-7 continued)

Lab. number	Results	Range	Mean	Percent deviation from amount added	Method	Reference
7112	0.06 0.05 0.06	0.01	0.06	20	Dithizone	54
7222	0.06 0.05 0.05	0.01	0.05	0	Dithizone	54
7526	0.02 0.02 0.02	0.00	0.02	60	Dithizone	22
7813	0.11 0.10 0.12	0.02	0.11	120	Dithizone	54
8112	0.05 0.05 0.05	0.00	0.05	0	Dithizone	54
8222	0.04 0.04 0.04	0.00	0.04	20	Dithizone	54
8313	0.05 0.05 0.05	0.00	0.05	0	Dithizone	54

(Table A-7 continued)

Lab. number	Results	Range	Mean	Percent deviation from amount added	Method	Reference
8423	0.07 0.07 0.06	0.01	0.07	40	Dithizone	54
8512	0.05 0.05 0.05	0.00	0.05	0	Dithizone	54
8613	0.04 0.04 0.04	0.00	0.04	20	Dithizone	54

Table A-8. TABULATION OF RESULTS FOR CHROMIUM
(0.11 mg/l added to water sample)

Lab. number	Results	Range	Mean	Percent deviation from amount added	Method	Reference
010	0.14 0.08 0.10	0.06	0.11	0	Spectrograph	--
011	0.25 0.20 0.12	0.13	0.19	73	Spectrograph	56
013	0.09 0.09 0.09	0.00	0.09	18	Spectrograph	1
014	0.11 0.12 0.11	0.01	0.11	0	Permanganate-azide	2
017	0.17 0.18 0.22	0.06	0.19	73	Spectrograph	--
1114	0.04 0.04 0.04	0.00	0.04	64	Permanganate-azide	--
1311	0.09 0.09 0.09	0.00	0.09	18	Permanganate-azide	2

(Table A-8 continued)

Lab. number	Results	Range	Mean	Percent deviation from amount added	Method	Reference
1312	0.04 0.04 0.02	0.02	0.03	73	Diphenylcarbazide ?	23
1322	0.07 0.07 0.07	0.00	0.07	36	Permanganate-azide	2
1511	0.06 0.07 0.08	0.02	0.07	36	Permanganate-azide	2
1611	0.09 0.08 0.08	0.01	0.08	27	Alkaline-hypobromite	2
2411	0.10 0.10 0.11	0.01	0.10	9	Alkaline-hypobromite	2
2513	0.20 0.21 0.22	0.02	0.21	91	Permanganate-azide	2
2526	0.02 0.01 0.01	0.01	0.01	91	Diphenylcarbazide ?	24

(Table A-8 continued)

Lab. number	Results	Range	Mean	Percent deviation from amount added	Method	Reference
2611	0.06 0.05 0.06	0.01	0.06	45	Diphenylcarbazide + silver peroxide oxidation	--
2811	0.09 0.09 0.09	0.00	0.09	18	Permanganate-azide	2
2926	0.11 0.10 0.10	0.01	0.10	9	Alkaline hypobromite	2
3111	0.12 0.12 ----	0.00	0.12	9	Alkaline-hypobromite	2
3211	0.00 0.00 0.00	0.00	0.00	100	Permanganate-azide	2
3226	0.11 0.10 0.10	0.01	0.10	9	Diphenylcarbazide ?	32
3611	0.09 0.09 0.09	0.00	0.09	18	Permanganate-azide	2

(Table A-8 continued)

Lab. number	Results	Ran	Mean	Percent deviation from amount added	Method	Reference
3716	0.02 0.03 0.03	0.01	0.03	73	Permanganate-azide	2
3731	0.12 0.12 0.12	0.00	0.12	9	Diphenylcarbazide ?	2
3811	0.11 0.10 0.10	0.01	0.10	9	Permanganate-azide	2
3911	0.06 0.08 0.06	0.02	0.07	36	Alkaline-hypobromite	2
4321	0.11 0.11 ----	0.00	0.11	0	Permanganate-azide	2
4421	0.10 0.10 0.09	0.01	0.10	9	Permanganate-azide	2
4511	0.10 0.10 0.10	0.00	0.10	9	Permanganate-azide	2

(Table A-8 continued)

Lab. number	Results	Range	Mean	Percent deviation from amount added	Method	Reference
4511	0.10 ---- ----	----	0.10	9	Atomic absorption	--
4523	0.13 0.13 0.13	0.00	0.13	18	Polarograph	--
4611	0.14 0.14 0.13	0.01	0.14	27	Permanganate-azide	2
4711	0.08 0.07 0.08	0.01	0.08	27	Permanganate-azide	2
4921	0.00 0.00 0.00	0.00	0.00	100	Diphenylcarbazide (hexavalent chromium)	2
5111	0.09 0.10 0.10	0.01	0.10	9	Permanganate-azide (Lieber method)	39
5511	0.00 ---- ----	----	0.00	100	Diphenylcarbazide (hexavalent chromium)	2

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(Table A-8 continued)

Lab. number	Results	Range	Mean	Percent deviation from amount added	Method	Reference
5811	0.15 ---- ----	----	0.15	36	Polarograph	--
5811	0.05 0.06 0.06	0.01	0.06	45	Diphenylcarbazide ? (total chromium)	2
5913	0.11 0.10 0.11	0.01	0.11	0	Permanganate-azide	2
6111	0.20 0.18 0.18	0.02	0.19	73	Permanganate-azide	2
6211	0.05 0.06 0.05	0.01	0.05	55	Permanganate-azide	2
6314	0.03 0.03 0.03	0.00	0.03	73	Permanganate-azide	2
6512	0.10 0.10 0.10	0.00	0.10	9	Alkaline-hypobromite	2

(Table A-8 continued)

Lab. number	Results	Range	Mean	Percent deviation from amount added	Method	Reference
6552	0.02 0.01 0.01	0.01	0.01	91	Diphenylcarbazide (hexavalent chromium)	2
6811	0.11 0.11 0.10	0.01	0.11	0	Permanganate-azide	2
6811	0.11 ---- ----	----	0.11	0	Polarograph	--
7112	0.05 0.04 0.05	0.01	0.05	55	Alkaline-hypobromite	2
7222	0.09 0.09 0.08	0.01	0.09	18	Permanganate-azide	2
7512	0.10 0.08 0.08	0.02	0.09	18	Permanganate-azide	2
7522	0.11 0.11 0.12	0.01	0.11	0	Permanganate-azide	2

(Table A-8 continued)

Lab. number	Results	Range	Mean	Percent deviation from amount added	Method	Reference
7526	0.15 0.16 0.12	0.04	0.14	27	Permanganate-azide	2
7622	0.10 0.10 0.10	0.00	0.10	9	Permanganate-azide	2
7813	0.12 0.12 0.12	0.00	0.12	9	Diphenylcarbazide ?	--
8112	0.09 0.09 0.09	0.00	0.09	18	Permanganate-azide	2
8222	0.01 0.01 0.01	0.00	0.01	91	Diphenylcarbazide (hexavalent chromium)	2
8423	0.08 0.10 0.09	0.02	0.09	18	Diphenylcarbazide	48
8512	0.10 0.09 ----	0.01	0.10	9	Permanganate-azide	2
8613	0.09 0.08 0.10	0.02	0.09	18	Permanganate-azide	48

Table A-9. TABULATION OF RESULTS FOR LEAD
(0.07 mg/l added to water sample)

Lab. number	Results	Range	Mean	Percent deviation from amount added	Method	Reference
011	0.16 0.22 0.10	0.12	0.16	150	Spectrograph	56
013	0.06 0.06 0.06	0.00	0.06	17	Spectrograph	1
014	0.06 0.06 0.06	0.00	0.06	17	Dithizone	55
015	0.09 0.09 0.08	0.01	0.09	29	Atomic absorption	8
017	0.05 0.06 ----	0.01	0.06	17	Spectrograph	--
1114	0.08 0.08 0.08	0.00	0.08	17	Dithizone	55
1214	0.02 0.02 ----	0.00	0.02	72	Dithizone	55

(Table A-9 continued)

Lab. number	Results	Range	Mean	Percent deviation from amount added	Method	Reference
1311	0.15 0.13 ----	0.02	0.14	100	Dithizone	55
1312	0.37 0.34 (0.06)	0.03 not included in average	0.36	415	Dithizone	55
1511	0.05 0.05 0.05	0.00	0.05	29	Dithizone	55
1611	0.08 0.08 0.07	0.01	0.08	14	Dithizone	55
1924	0.06 0.06 0.06	0.00	0.06	14	Dithizone	55
2513	0.10 0.10 0.10	0.00	0.10	43	Dithizone	55
2526	0.05 0.06 0.07	0.02	0.06	14	Dithizone	55

(Table A-9 continued)

Lab. number	Results	Range	Mean	Percent deviation from amount added	Method	Reference
2611	0.07 0.07 0.07	0.00	0.07	0	Dithizone	55
2811	0.07 0.07 0.06	0.01	0.07	0	Dithizone	55
2926	0.07 0.07 0.07	0.00	0.07	0	Dithizone	55
3111	0.07 0.07 ----	0.00	0.07	0	Dithizone	55
3211	0.07 0.07 0.07	0.00	0.07	0	Dithizone	55
3226	0.08 0.08 0.08	0.00	0.08	14	Atomic absorption	50
3636	0.10 0.10 0.10	0.00	0.10	43	Dithizone	55

(Table A-9 continued)

Lab. number	Results	Range	Mean	Percent deviation from amount added	Method	Reference
3716	0.06 0.06 0.06 0.04	0.02	0.05	29	Dithizone	55
3731	0.13 0.12 0.14	0.02	0.13	86	Dithizone	55
3811	0.08 0.08 0.08	0.00	0.08	14	Dithizone	2
3816	0.08 0.08 0.08	0.00	0.08	14	Dithizone	55
3911	0.08 0.08 0.08	0.00	0.08	14	Dithizone	55
4211	0.10 0.10 0.10	0.00	0.10	43	Dithizone	2
4321	0.06 0.06 ----	0.00	0.06	14	Dithizone	55

(Table A-9 continued)

Lab. number	Results	Range	Mean	Percent deviation from amount added	Method	Reference
4421	0.05 0.04 0.05	0.01	0.05	29	Dithizone	55
4511	0.08 0.08 0.08	0.00	0.08	14	Dithizone	55
4523	0.07 0.06 0.07	0.01	0.07	0	Polarograph	--
4711	0.06 0.06 0.06	0.00	0.06	14	Dithizone	55
4921	0.09 0.11 0.14	0.05	0.11	57	Dithizone	55
5111	0.30 0.23 0.30	0.07	0.28	300	Dithizone	55
5511	0.07 0.07 0.07	0.00	0.07	0	Dithizone	55

(Table A-9 continued)

Lab. number	Results	Range	Mean	Percent deviation from amount added	Method	Reference
5611	0.14 ---- ----	----	0.14	100	Polarograph	--
5811	0.08 0.08 0.09	0.01	0.08	14	Dithizone	55
5913	1.38 1.36 1.40	0.04	1.38	1870	Polarograph	33
6111	0.08 ---- ----	----	0.08	14	Dithizone	55
6211	0.06 0.05 0.06	0.01	0.06	14	Dithizone	2
6411	0.04 0.04 0.04	0.00	0.04	43	Dithizone	55
6512	0.06 0.06 0.06	0.00	0.06	14	Dithizone	55

(Table A-9 continued)

Lab. number	Results	Range	Mean	Percent deviation from amount added	Method	Reference
6552	0.07 0.07 0.07	0.00	0.07	0	Dithizone	55
6621	0.09 0.10 0.08	0.02	0.09	29	Dithizone	55
6715	0.06 0.05 0.07	0.02	0.06	14	Dithizone	55
6811	0.10 0.07 0.12	0.05	0.10	43	Dithizone	55
6914	0.06 0.07 0.07	0.01	0.07	0	Dithizone	41
7112	0.09 0.10 0.10	0.01	0.10	43	Dithizone	55
7222	0.09 0.09 0.10	0.01	0.09	29	Dithizone	55

(Table A-9 continued)

Lab. number	Results	Range	Mean	Percent deviation from amount added	Method	Reference
7512	0.04 0.03 0.04	0.01	0.04	43	Dithizone	55
7531	0.20 0.20 ----	0.00	0.20	186	Dithizone	43
7813	0.19 0.20 0.20	0.01	0.20	186	Dithizone	55
8112	0.07 0.08 0.08	0.01	0.08	14	Dithizone	55
8222	0.08 0.08 0.10	0.02	0.09	29	Dithizone	55
8313	0.06 0.06 0.07	0.01	0.06	14	Dithizone	55
8423	0.00 0.00 0.00	0.00	0.00	100	Dithizone	55
8613	0.07 0.07 0.07	0.00	0.07	0	Dithizone	55

APPENDIX B.

GLOSSARY OF STATISTICAL TERMS

This glossary of statistical terms defined as they are used in the report is presented to ensure uniform and complete understanding.

Arithmetic mean	Sum of a series of test results divided by the number of tests in the series.
Median	Value above and below which an equal number of observations lie.
Accuracy	Correctness of a measurement or the degree of correspondence between the results and the true value (actual amount added).
Accuracy Data	Measurements that relate to the difference between the average test results and the true value when the latter is known or assumed. The following measures apply: 50% Range - Maximum deviation from the true value for the more accurate half of the mean results reported. Average deviation from true value - Average difference (always taken so as to be positive) between the mean determined for each laboratory and the true value. Average percent deviation from true value - Average of the differences between a laboratory's replicate results and the true value expressed as percentage of the true value.
Precision	Measure of the reproducibility of measurements, or the degree to which the measurements correspond to one another.
Precision Data	Measurements that relate to the variation among the test results themselves, i.e., the scatter or dispersion of a series of test results without assumption of any prior information. The following measures apply:

Variance - Sum of squares of deviations of the average test results from the mean of the series divided by one less than the total number of average test results.

Standard deviation - Square root of the variance.

Coefficient of variation - Standard deviation expressed as a percentage of the mean of a series of laboratory results.

Range - Difference in magnitude between the highest and lowest laboratory mean.

Average percent deviation within laboratory - Average of the differences between the replicate results from a laboratory and the mean of these results expressed as percentage of their mean.

Confidence limits - Limits within which the true mean of the population (the theoretically infinite number of possible replications of the analysis) will lie with a given probability.

APPENDIX C.

ANALYTICAL REFERENCE SERVICE MEMBERSHIP

STATE AGENCIES

Alabama Water Improvement Commission, Montgomery
Arizona State Department of Public Health, Phoenix
Arkansas State Department of Health, Little Rock
California Department of Water Resources, Los Angeles
California Department of Water Resources, Sacramento
California State Department of Public Health, Los Angeles
California State Department of Public Health, Air and Industrial Hygiene Laboratory, Berkeley
California State Department of Public Health, Sanitation and Radiation Laboratory, Berkeley
Colorado Department of Public Health, Denver
Connecticut State Department of Health, Hartford
Delaware Water Pollution Commission, Dover
Florida State Board of Health, Jacksonville
Florida State Board of Health, Miami
Florida State Board of Health, Pensacola
Florida State Board of Health, Winter Haven
Georgia Department of Public Health, Atlanta
Hawaii Department of Health, Laboratories Branch, Honolulu
Hawaii Department of Health, Occupational and Radiological Health Section, Honolulu
Idaho Department of Health, Boise
Illinois Department of Air Pollution Control, Chicago
Illinois Department of Public Health, Springfield
Illinois Department of Public Health, State Sanitary Water Board, Springfield
Illinois State Water Survey Division, Champaign
Indiana State Board of Health, Indianapolis
Iowa State Hygienic Laboratory, Iowa City
Kansas State Department of Health, Topeka
Kentucky State Department of Health, Division of Laboratory Services, Frankfort
Kentucky State Department of Health, Public Health Laboratories Division, Frankfort
Kentucky State Department of Health, Radiological Health Program, Frankfort
Louisiana State Board of Health, New Orleans
Maryland State Department of Health, Baltimore
Massachusetts Department of Public Health, Amherst
Massachusetts Department of Public Health, Boston
Michigan State Department of Health, Lansing

Michigan Water Resources Commission, Lansing
Minnesota Department of Health, Engineering Laboratories Section, Minneapolis
Missouri Department of Public Health and Welfare, Jefferson City
Montana Bureau of Mines and Geology, Butte
Montana State Board of Health, Helena
Nebraska Department of Agriculture and Economic Development, Lincoln
Nebraska State Department of Health, Division of Radiological Health, Lincoln
Nevada State Department of Health, Las Vegas
Nevada State Department of Health, Reno
New Hampshire Department of Health, Concord
New Hampshire Water Pollution Commission, Concord
New Jersey State Department of Health, Trenton
New Jersey State Department of Health, Air Sanitation Program, Trenton
New Jersey State Department of Health, Radiological Health Program, Trenton
New Mexico Department of Public Health, Santa Fe
New York State Air Pollution Control Board, Albany
New York State Conservation Department, Oakdale, L.I.
New York State Conservation Department, Scottsville
New York State Department of Air Pollution Control, New York City
New York State Department of Health, Albany
North Carolina Department of Water Resources, Raleigh
North Dakota State Department of Health, Bismarck
Ohio Department of Agriculture, Reynoldsburg
Ohio State Department of Health, Columbus
Oklahoma State Health Department, Oklahoma City
Oregon State Board of Health, Division of Sanitation and Engineering, Portland
Pennsylvania Department of Agriculture, Harrisburg
Pennsylvania Department of Health, Bureau of Air Pollution Control, Pittsburgh
Pennsylvania Department of Health, Division of Air Pollution Control, Harrisburg
Pennsylvania Department of Health, Division of Sanitary Engineering, Harrisburg
Puerto Rico Aqueduct and Sewer Authority
Rhode Island State Department of Health, Providence
South Carolina Department of Agriculture, Columbia
South Carolina Pollution Control Authority, Columbia
South Dakota Department of Health, Pierre
Tennessee Department of Public Health, Division of Industrial Hygiene Service, Nashville
Tennessee Department of Public Health, Radiological Health Service, Nashville
Tennessee Stream Pollution Control Board, Nashville

Texas State Department of Health, Austin
Texas State Department of Health, Division of Occupational Health and Radiation Control, Austin
Utah State Department of Health, Salt Lake City
Vermont Department of Water Resources, Montpelier
Vermont State Department of Health, Barre
Vermont State Public Health Laboratory, Burlington
Virginia State Department of Health, Bureau of Industrial Hygiene, Richmond
Virginia State Department of Health, Bureau of Laboratories, Richmond
Virginia State Water Control Board, Richmond
Washington State Department of Health, Seattle
Washington State Food and Drug Laboratory, Seattle
West Virginia Department of Natural Resources, Charleston
Wisconsin Department of Agriculture, Madison
Wisconsin State Laboratory of Hygiene, Madison

MUNICIPAL AGENCIES

Baltimore Health Department, Maryland
Beaumont Health Department, Texas
Bureau of Air Pollution Control and Heating Inspection, Cincinnati, Ohio
Central District Filtration Plant, Chicago, Illinois
Charlotte Water Department, North Carolina
City of Allentown, Bureau of Water, Pennsylvania
City of Durham, Department of Water Resources, North Carolina
City of Erie, Bureau of Water, Pennsylvania
City of Kingston Laboratory, New York
City of Los Angeles, Department of Water and Power, California
City of Miami, Alexander Orr, Jr. Water Treatment Plant, Florida
City of New York, Department of Health, New York
City of New York, Department of Health, Food and Drug Laboratory, New York
City of Niagara Falls, Division of Water Laboratories, New York
City Water Department of Chattanooga, Tennessee
City of Yonkers, Bureau of Water, New York
Department of Health and Hospitals, St. Louis, Missouri
Department of Public Works and Utilities, Flint, Michigan
Department of Service and Buildings, Dayton, Ohio
Erie County Laboratory, Buffalo, New York
Fresno Department of Public Health, California
Houston Health Department, Texas
Lawrence Experiment Station, Massachusetts
Long Beach Water Department, California
Los Angeles Air Pollution Control District, California
Los Angeles County Air Pollution Control District, California
Los Angeles County Flood Control District, California
Los Angeles Department of Public Works, California

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Louisville Water Company, Kentucky
Metropolitan Utilities District, Omaha, Nebraska
Metropolitan Water District of Southern California, La Verne, California
Minneapolis Water Department, Minnesota
Monroe County Department of Health, Rochester, New York
Nassau County Department of Health, Hempstead, New York
Nassau County Department of Health, Mineola, New York
Newburgh Water Department, New York
Orange County Air Pollution Control District, Anaheim, California
Pasadena Department of Public Health, California
Philadelphia Department of Public Health, Environmental Health Laboratory, Pennsylvania
Philadelphia Department of Public Health, Public Health Laboratory, Pennsylvania
Philadelphia Suburban Water Company, Bryn Mawr, Pennsylvania
Philadelphia Water Department, Pennsylvania
Philadelphia Water Department, Belmont Laboratory, Pennsylvania
Philadelphia Water Department, Torresdale Laboratory, Pennsylvania
St. Louis County Water Company, Missouri
Springwells Filtration Plant, Dearborn, Michigan
Topeka Water Department, Kansas
Water Pollution Control Board, Cincinnati, Ohio

FEDERAL AGENCIES

Associated Universities Incorporated, Brookhaven National Laboratory, Upton, Long Island, New York
DHEW, Food and Drug Administration, Chicago, Illinois
DHEW, Food and Drug Administration, Division of Pharmacology, Washington, D.C.
DHEW, PHS, Air Pollution Technical Information Center, Division of Air Pollution, Washington, D.C.
DHEW, PHS, Communicable Disease Center, Savannah, Georgia
DHEW, PHS, Division of Dental Public Health. Bethesda, Maryland
DHEW, PHS, Division of Environmental Engineering and Food Protection, Washington, D.C.
DHEW, PHS, Great Lakes-Illinois River Basins Project, Chicago, Illinois
DHEW, PHS, Information and Education Office, Division of Air Pollution, Washington, D.C.
DHEW, PHS, Interstate Carrier Branch, Division of Environmental Engineering and Food Protection, Washington, D.C.
DHEW, PHS, Northeast Shellfish Sanitation Research Center, Narragansett, Rhode Island
DHEW, PHS, Northeastern Radiological Health Laboratory, Winchester, Massachusetts
DHEW, PHS, Office of Chief, Division of Water Supply and Pollution Control, Washington, D.C.

DHEW, PHS, Ohio River Basin Project, Division of Water Supply and Pollution Control, Wheeling, West Virginia
DHEW, PHS, Pacific Northwest Water Laboratory, Corvallis, Oregon
DHEW, PHS, Radiological Health Laboratory, Rockville, Maryland
DHEW, PHS, Regional Office IV, Atlanta, Georgia
DHEW, PHS, Research and Training Grants Branch, Division of Water Supply and Pollution Control, Washington, D.C.
DHEW, PHS, Southeastern Radiological Health Laboratory, Montgomery, Alabama
DHEW, PHS, Southwestern Radiological Health Laboratory, Las Vegas, Nevada
DHEW, PHS, Technical Services Branch, Division of Water Supply and Pollution Control, Washington, D.C.
DHEW, PHS, Water Quality, Division of Water Supply and Pollution Control, Cincinnati, Ohio
District of Columbia Department of Public Health, Washington, D.C.
Fourth U.S. Army Medical Laboratory, Fort Sam Houston, Texas
Oak Ridge Institute of Nuclear Studies, Oak Ridge, Tennessee
Pearl Harbor Naval Shipyard, San Francisco, California
Regional Environmental Health Laboratory, McClellan AFB, California
San Francisco Bay Naval Shipyard, Vallejo, California
Sixth U.S. Army Medical Laboratory, Fort Baker, California
Tennessee Valley Authority, Chattanooga, Tennessee
Tennessee Valley Authority, Wilson Dam, Alabama
2794th USAF Dispensary, Kelly AFB, Texas
USAF Hospital (HWEBB), Wright Patterson AFB, Ohio
U.S. Army Environmental Hygiene Agency, Edgewood Arsenal, Maryland
U.S. Bureau of Sports, Fisheries, and Wildlife, Fish-Pesticide Research Laboratory, Denver, Colorado
U.S. Department of the Interior, Bureau of Reclamation, Denver, Colorado
U.S. Department of the Interior, Geological Survey, Columbus, Ohio
U.S. Department of the Interior, Geological Survey, Denver, Colorado
U.S. Department of the Interior, Geological Survey, Little Rock, Arkansas
U.S. Department of the Interior, Geological Survey, Philadelphia, Pennsylvania
U.S. Department of the Interior, Geological Survey, Sacramento, California
Walter Reed Army Medical Center, Washington, D.C.
Water Pollution Control Federation, Washington, D.C.

FOREIGN AGENCIES

British Coke Research Association, Chesterfield, Derbyshire, England
Central Electricity Research Laboratories, Leatherhead, Surrey, England
City's Institute for Health Protection, Belgrade, Yugoslavia
Comissao Inter-Municipal de Controle da Poluicao das Aguas E Do Ar, Sao Paulo, Brazil
Department of Health Services and Hospital Insurance, Vancouver, Canada
Department of Mines and Technical Survey, Ottawa, Ontario, Canada

Department of Municipal Laboratories, Hamilton, Ontario, Canada
Department of National Health and Welfare, Vancouver, Canada
Department of National Health and Welfare, Occupational Health Division, Ottawa, Ontario, Canada
Department of National Health and Welfare, Public Health Engineering Division, Ottawa, Ontario, Canada
Instituto Nacional de Obras Sanitarias, Caracas, Venezuela
Israel Institute of Technology, Haifa, Israel
Metropolitan Corporation of Greater Winnipeg, Winnipeg, Manitoba, Canada
Metropolitan Water, Sewage, and Drainage Board, Sydney, Australia
Ministere de la Sante, Montreal, Quebec, Canada
National Institute of Hygienic Sciences, Tokyo, Japan
National University of Colombia, Bogota, Colombia
Newcastle and Gateshead Water Company, Newcastle Upon Tyne, England
Obras Sanitarias de la Nacion, Buenos Aires, Argentina
Permutit Company, Limited, London, England
Public Health Laboratory Service, London, England
Scientific Research Council, Kingston, Jamaica, West Indies
Taiwan Institute of Environmental Sanitation, Air Pollution and Radiological Health Section, Taipei, Taiwan, China
Taiwan Institute of Environmental Sanitation, Division of Water Quality and Pollution Control, Taipei, Taiwan, China
Taiwan Institute of Environmental Sanitation, PHA, Taiwan, China
Taiwan Institute of Environmental Sanitation, Taichung Water Laboratory, Taichung, Taiwan, China
Taiwan Institute of Environmental Sanitation, Tainan Water Laboratory, Tainan, Taiwan, China
Taiwan Institute of Environmental Sanitation, Taitung Water Laboratory, Taitung, Taiwan, China
Taiwan Institute of Environmental Sanitation, Training Section, Taipei, Taiwan, China
United Kingdom Atomic Energy Authority, Didcot, Berks, England
University of Beograd, Beograd, Yugoslavia
University of Leeds, Leeds, England
Waste Water Research Laboratory of the Swedish Forest Industries, Stockholm, Sweden
Water Research Association, Marlow, Buckinghamshire, England

UNIVERSITIES

University of California, Richmond
University of California, Riverside
University of California, Engineering Material Laboratory, Berkeley
University of California, Industrial Hygiene Engineering, Berkeley
Clemson University, South Carolina
Columbia University, Plainsboro, New Jersey
Cornell University, Ithaca, New York

University of Dayton, Ohio
Drexel Institute of Technology, Philadelphia, Pennsylvania
Fairleigh Dickinson University, Madison, New Jersey
University of Florida, College of Engineering, Gainesville
Iowa State College, Ames
University of Kansas, Lawrence
Louisiana State University, Baton Rouge
University of Minnesota, Minneapolis
University of North Carolina, Chapel Hill
University of Pittsburgh, Pennsylvania
Purdue University, Lafayette, Indiana
Rennselaer Polytechnic Institute, Troy, New York
Rutgers - The State University, Department of Agricultural Chemistry, New Brunswick, New Jersey
Rutgers - The State University, Department of Environmental Science, New Brunswick, New Jersey
St. Mary's College, Winona, Minnesota
University of Vermont, Burlington
Washington State University, Pullman

INDUSTRIES

American Cyanamid Company, Wayne, New Jersey
Anaconda Company, Grants, New Mexico
Battelle Memorial Institute, Columbus, Ohio
Bender Hygienic Laboratory, Albany, New York
Bethlehem Steel Company, Bethlehem, Pennsylvania
Bio-Technics Laboratories, Incorporated, Los Angeles, California
Borg-Warner Corporation, Des Plaines, Illinois
Brown and Caldwell Laboratories, San Francisco, California
Calgon Corporation, Pittsburgh, Pennsylvania
California Water Service Company, San Jose, California
Chrysler Corporation, Detroit, Michigan
Culligan Incorporated, Northbrook, Illinois
Dow Chemical, Midland, Michigan
E.I. du Pont de Nemours and Company, Aiken, South Carolina
Ekroth Laboratories, Incorporated, Brooklyn, New York
FMC Corporation, Pocatello, Idaho
Fairbanks, Morse and Company Research Center, Beloit, Wisconsin
General Electric Company, Louisville, Kentucky
Good Year Atomic Corporation, Piketon, Ohio
H.C. Nutting Company, Cincinnati, Ohio
Hammond-Montel, Incorporated, Elmhurst, New York
Havens-Emerson, Oradell, New Jersey
Hazleton Nuclear Science Corporation, Palo Alto, California
Holzmacher, McLendon and Murrell, Melville, New York
Industrial Chemicals, Incorporated, South Bend, Indiana

INFILCO, General American Transportation Corporation, Tucson, Arizona
Ionics, Incorporated, Watertown, Massachusetts
Johns-Manville Research and Engineering Center, Manville, New Jersey
Kem-Tech Laboratories, Incorporated, Baton Rouge, Louisiana
Kennecott Copper Corporation, Salt Lake City, Utah
Magnus Chemical, Garwood, New Jersey
Mallinckrodt Chemical Works, St. Louis, Missouri
Maryland Cooperative Milk Producers, Incorporated, Baltimore, Maryland
McCrone Associates, Incorporated, Chicago, Illinois
Midwest Research Institute, Kansas City, Missouri
Minute Maid Company, Anaheim, California
Monsanto Company, St. Louis, Missouri
NALCO Chemical Company, Chicago, Illinois
Nuclear-Chicago Corporation, Des Plaines, Illinois
Pacific Gas and Electric Company, Emeryville, California
Pacific Gas and Electric Company, San Francisco, California
Pan American World Airways, Patrick Air Force Base, Florida
Pomeroy, Johnston, and Bailey, Pasadena, California
Radiation Applications, Incorporated, Long Island, New York
Radiation Detection Company, Mountain View, California
Ray W. Hawksley Company, Incorporated, Richmond, California
Reynolds Electrical and Engineering Company, Incorporated, Las Vegas, Nevada
Roy F. Weston, Incorporated, West Chester, Pennsylvania
Sandia Corporation, Albuquerque, New Mexico
Shell Chemical Company, Princeton, New Jersey
Southern Testing and Research Laboratories, Incorporated, Wilson, North Carolina
Tracerlab, Incorporated, Richmond, California
U.S. Industrial Chemicals Company, Tuscola, Illinois
W.R. Grace and Company, Dearborn Chemical Division, Lake Zurich, Illinois
Water Service Laboratories, Incorporated, New York, New York

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